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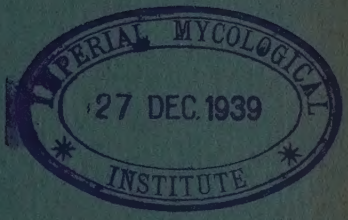

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Volume XXIV, № 5

TABLE DES MATIÈRES

MATHÉMATIQUES Pages

Loo-Keng Hua (Лу-Кинг Хуа). On a Lemma Due to Vinogradow . . . 419

THÉORIE DE L'ÉLASTICITÉ

M. I. Gorbunov-Possadov (М. И. Горбунов-Посадов). On Beams and Rectangular Plates Supported by an Elastic Half-Space 421

PHYSIQUE

M. J. Shirobokov (М. Я. Широбоков). On the Mecanism of Cobalt Magnetization. 426

V. Antonov-Romanovsky (В. Антонов-Романовский) and G. Kochergin (Г. Кочергин). On the Decay of Alkali-Haloid Phosphors Activated by Thallium. 430

M. Divilkovsky (М. Дивильковский). Méthode absolue de mesure de la constante diélectrique et des pertes dans les liquides à ondes décimétriques. 433

BIOPHYSIQUE

N. N. Malov (Н. Н. Малов). Die elektrischen Eigenschaften des Blutes unter der Wirkung der Dezimeterwellen. 437

CHIMIE

A. I. Kiesber (А. И. Кизбер). A New Method for the Synthesis of Amino-Carboxylic Acids of the Aromatic Series 440

BIOCHIMIE

A. Shmuck (А. Шмук) and A. Gusseva (А. Гусева). Chemical Structure of Substances Inducing Polyploidy in Plants. 441

GÉOLOGIE

J. K. Dzevanovsky (Ю. К. Дзевановский). On the Geology of the Crystalline Complex of the Eastern Margin of the Aldan Platform. . . . 447

MINÉRALOGIE Pages

M. P. Lozhechkin (М. П. Ложечкин). New Data on the Chemical Composition of «Gold Cupride». 451

N. E. Efremov (Н. Е. Ефремов). Zonal Distribution of Ultra-Basites of the Caucasus Range 455

CRISTALLOGRAPHIE

N. A. Toropov (Н. А. Торопов) and M. M. Stukalova (М. М. Стукалова). Interchange of Bases in Crystals of Beta-Alumina. 459

GÉNÉTIQUE

J. M. Olenov (Ю. М. Оленов) and I. S. Kharmac (И. С. Харман). Transformation of the Normal Genotype in Wild *Drosophila melanogaster* Populations. 462

J. M. Olenov (Ю. М. Оленов), I. S. Kharmac (И. С. Харман), K. F. Galkovskaya (К. Ф. Галковская) and G. D. Muretov (Г. Д. Муретов). Factors Responsible for the Genic Composition of Wild *Drosophila melanogaster* Populations 466

G. D. Muretov (Г. Д. Муретов). Physiological Mutations and Dynamics of the Genic Composition of *Drosophila melanogaster* Populations. . . 471

M. E. Neuhaus (М. Е. Нейгауз). Dependence between the Quantity of the *cn*-Substance and the Strength of its Action in *Drosophila melanogaster*. 475

Dontcho Kostoff (Дончо Костов). Frequency of Polyembryony and Chlorophyll Deficiency in Rye. 479

V. A. Rybin (В. А. Рыбин). Tetraploid Plants of *Vicia faba* Produced by Colchicine Treatment. 483

V. I. Ivanov (В. И. Иванов). Formation of Polyploid Forms in *Solanum* Sect. *Tuberarium*. 486

PHYSIOLOGIE VÉGÉTALE

B. S. Moshkov (Б. С. Мошков). Transfer of Photoperiodic Reaction from Leaves to Growing Points 489

O. A. Gashkova (О. А. Гашкова). Plant's Response to Sharp Variation of Temperature. 492

P. I. Grekov (П. И. Греков). Double Supply of Endosperm to Spring Wheat Seed Embryo. 496

E. G. Petrov (Е. Г. Петров) and N. I. Gavrilov (Н. И. Гаврилов). Device for Determining Leaves Area 499

V. Glotov (В. Глотов). Effect of Colchicine from *Colchicum umbrosum* Stev. on the Camphor Basil. 502

L. P. Zhdanova (Л. П. Жданова). Mechanism of Auxin Formation in Green Plant. 505

S. M. Mashtakov (С. М. Маштаков). Qualitative Variations of Rubber in the Roots of Kok-Saghyz at the Second Year of Vegetation. 509

AGROPHYSIOLOGIE

S. O. Grebinsky (С. О. Гребинский). Biochemical Features of Alpine Fodder Plants. 513

CYTOLOGIE

E. V. Ivanovskaja (Е. В. Ивановская). A Haploid Plant of *Solanum tuberosum* L. 517

Rédacteur en chef A. Fersman. **Rédacteur S. Bernstein.**

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MATHEMATICS

ON A LEMMA DUE TO VINOGRADOW

By LOO-KENG HUA

(Communicated by I. M. Vinogradow, Member of the Academy, 14. VI. 1939)

It was recently proved by I. Vinogradow[1] that if P is a large integer,

$$\int_0^1 \cdots \int_0^1 \left| \sum_{x=0}^{P} e^{2\pi i (\alpha_n x^n + \cdots + \alpha_1 x)} \right|^r d\alpha_1 \ldots d\alpha_n \ll P^{r-\frac{1}{2}n(n+1)}$$

for the greatest even r satisfying

$$r < Ln(n+1)(n+2) \log n,$$

where $L = L_n$ is given by the following table

n	2	3	4	5	6	7	8	9	10	11	12	13	$\geqslant 14$
L	4.81	4.45	4.34	4.30	4.29	4.23	4.22	4.18	4.16	4.15	4.14	4.12	4.10

This result is very important and has numerous applications, e. g., in Waring's problem, Tarry's problem and the estimation of trigonometrical sums. Now I am able to improve the result for smaller n. In fact for $n \leqslant 10$ and

$$s = 2n + 2^t\left(\frac{1}{2}(t+1)(t+2) - n\right) + 2^{t+1}(t+2) + \ldots + 2^{n-1}n,$$

where t is the least integer such that $\frac{1}{2}(t+1)(t+2) \geqslant n$, we have

$$\int_0^1 \cdots \int_0^1 \left| \sum_{x=0}^{P} e^{2\pi i (\alpha_n x^n + \cdots + \alpha_1 x)} \right|^s d\alpha_1 \ldots d\alpha_n \ll P^{s-\frac{1}{2}n(n+1)+\varepsilon}$$

where the constant implied by the symbol $\ll$ depends on n and ε only, and ε is any positive number.

In order to make a comparison, we have the following table for the values of r and s:

n	2	3	4	5	6	7	8	9	10
r	80	293	721	1453	2582	4148	6318	9092	12644
s	6	18	48	126	316	758	1776	4074	9188

The method of proof depends essentially on what I used in my preceding paper [2] with a very complicated modification. By the method analogous to that of I. Vinogradow, a number of results may be expected.

On the contrary, for $2t > \frac{1}{2}n(n+1)$ we have

$$\int_0^1 \dots \int_0^1 \left| \sum_{x=0}^{P} e^{2\pi i(\alpha_n x^n + \dots + \alpha_1 x)} \right|^{2t} d\alpha_1 \dots d\alpha_n \gg P^{2t-\frac{1}{2}n(n+1)}.$$

The proof of this result is very easy and proceed as follows:

$$\int_0^1 \dots \int_0^1 \left| \sum_{x=0}^{P} e^{2\pi i(\alpha_n x^n + \dots + \alpha_1 x)} \right|^{2t} d\alpha_1 \dots d\alpha_n \gg \int_0^{P-n} d\alpha_n \dots$$

$$\dots \int_0^{P-1} d\alpha_1 \left| \sum_{x=0}^{P} e^{2\pi i(\alpha_n x^n + \dots + \alpha_1 x)} \right|^{2t} =$$

$$= \int_0^{P-n} d\alpha_n \dots \int_0^{P-1} d\alpha_1 \left(\left| \int_0^{P} e^{2\pi i(\alpha_n x^n + \dots + \alpha_1 x)} dx \right|^{2t} + 0\left(P^{2t-1}\right) \right)^{(3)} =$$

$$= P^{2t-\frac{1}{2}n(n+1)} \int_0^1 \dots \int_0^1 \left| \int_0^1 e^{2\pi i(\alpha_n x^n + \dots + \alpha_1 x)} dx \right|^{2t} d\alpha_1 \dots d\alpha_n +$$

$$+ 0\left(P^{2t-1-\frac{1}{2}n(n+1)}\right) \gg P^{2t-\frac{1}{2}n(n+1)}.$$

Actually, we can find the asymptotic formula for

$$\int_0^1 \dots \int_0^1 \left| \sum_{x=0}^{P} e^{2\pi i(\alpha_n x^n + \dots + \alpha_1 x)} \right| d\alpha_1 \dots d\alpha_n.$$

China.

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THEORY OF ELASTICITY

ON BEAMS AND RECTANGULAR PLATES SUPPORTED BY AN ELASTIC HALF-SPACE

By M. I. GORBUNOV-POSSADOV

(Communicated by S. L. Soboleff, Member of the Academy, 5. V. 1939)

1. The problem of calculation of beams supported by an elastic half-space has been considered by many authors, predominantly by Soviet authors ([1-8]). But in their solutions of the problem these authors started in the way of approximation either from the conditions of the plane problem of the theory of elasticity, or, when they considered the problem as a three-dimensional one, they introduced arbitrary simplifying assumptions. The solution which we propose is given under the exact conditions of the three-dimensional problem. The solution uses our formula for the determination of the deformation of the surface of an elastic half-space under an arbitrary load, the distribution law of which over a rectangular area is expressed by a function with continuous first derivatives. This formula permits also to solve the problem on absolutely rigid rectangular plates supported by an elactic half-space and gives the necessary basis for developing a method of calculation of plates of finite rigidity.

2. The vertical displacements $w(x, y)$ of the surface of an elastic half-space under normal pressures $p(x, y)$ distributed over a rectangle with the sides $2a$ and $2b$ are, by Boussinesq's equation ([9]):

$$w(x, y) = \frac{(1-\nu_0^2)\,ab}{\pi E_0} \int_{-1}^{1}\int_{-1}^{1} \frac{p(\bar{x}, \bar{y})\, d\bar{x} d\bar{y}}{\sqrt{a^2(\bar{x}-x)^2 + b^2(\bar{y}-y)^2}}. \qquad (1)$$

In formula (1) ν_0 and E are respectively Poisson's coefficient and the modulus of elasticity of the foundation; x and y are the co-ordinates of the point under displacement referred to the half-sides of the rectangle $\left(x = \frac{x'}{a},\ y = \frac{y'}{a}\right.$, where x' and y' are the real co-ordinates$\left.\right)$; $\bar{x}$ and $\bar{y}$ are the correspondingly reduced co-ordinates of the load element. Their origin is placed in the center of the rectangle, the x-axis is directed parallel to the greater side $2a$. The double integral is extended over the whole area F of the rectangle.

Making in (1) the substitution

$$\bar{x} = x + \xi, \quad \bar{y} = y + \eta,$$

developing the numerator and the denominator of the integrand into double power series in ξ and η and integrating, we find an expression

by means of which we determine the displacements of the surface of the foundation for the given pressure with the help of simple quadratures. In the special case when the distribution law of the pressures is given in the form of an infinite double power series

$$p(x, y) = \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} a_{ij} x^i y^j, \tag{2}$$

the expression for $w(x, y)$ may be also written in the form of a double series:

$$w(x, y) = \frac{(1 - \nu_0^2)\, a}{\pi E_0} \sum_{u=0}^{\infty} \sum_{v=0}^{\infty} \left(\sum_{i=0}^{\infty} \sum_{j=0}^{\infty} c_{u,v,i,j}\, a_{ij} \right) x^u y^v, \tag{3}$$

where

$$c_{u,v,i,j} = i!\, j! \sum_{m=M}^{i} \sum_{n=N}^{j} \frac{\beta^{v-j} [(-1)^m + (-1)^{u+m-i}] [(-1)^n + (-1)^{v+n-j}]}{(i-m)!\, (j-n)!\, m!\, n!\, (u+m-i)!\, (v+n-j)!} \cdot$$

$$\cdot \frac{d^{v+n-j}}{d\beta^{v+n-j}} \int_0^{\beta} t^{n-u+i} \int_0^{\frac{1}{t}} \frac{d^{u+m-i}}{dz^{u+m-i}} \frac{z^m}{\sqrt{1+z^2}}\, dz\, dt \tag{4}$$

and $M = 0$ for $i \leqslant u$, $M = i - u$ for $i \geqslant u$, $N = 0$ for $j \leqslant v$, $N = j - v$ for $j \geqslant v$, $\beta = \frac{b}{a} \leqslant 1$.

3. However, at the calculation of beams and plates on an elastic foundation the law of pressures is unknown and the problem consists in its determination. In the case of absolutely rigid plates the solution is comparatively simple. For instance, in the case of a load symmetrical with respect to both co-ordinate axes we shall assume the pressure law to be of the form of the series (2), retaining in it, by virtue of symmetry, only terms with even powers of x and y and passing therefore to double indices $2i$, $2j$. Considering the equations (4), we remark that in the case when the function $p(x, y)$ is even, the series (3) must also contain only terms with even powers of x and y.

Integrating the equation (2), we write the equilibrium condition of the plate in the form

$$4ab \sum_{i=0}^{\infty} \sum_{j=0}^{\infty} \frac{a_{2i,2j}}{(2i+1)(2j+1)} = P \tag{5}$$

(P is the total load acting on the plate).

The equation (5) is the first of an infinte system of equations, the rest of which we obtain from the condition of constancy of the displacements under the plate by putting the coefficients of all products $x^{2u} y^{2v}$ (except $x^0 y^0$) in the equation (3) equal to zero. This infinite system we solve approximately by forming from it a «shortened» system of $\frac{n(n+3)}{2} + 1$ first equations for the same number of unknowns $a_{2i,2j}$, which gives us the possibility to find the coefficients of the polynomial of degree $2n$ approximating the series (2). Due to simple algebraical formulae calculated by us with the help of equations (4), which permit to determine the $c_{u,v,i,j}$ for $u, v, i, j \leqslant 6$, the solution for a plate with an arbitrary ratio of sides $\frac{b}{a} \leqslant 6$ may be carried out quickly enough.

For the square we thus obtain the following formula:

$$p(x, y) = [0.56 + 0.26(x^2 + y^2) + 0.30(x^4 + y^4) - 0.02x^2y^2 + \\ + 0.50(x^6 + y^6) + 0.03(x^4y^2 + x^2y^4)] \frac{P}{F}.$$

The sinking of the square stamp is

$$w = \frac{0.92(1 - \nu_0^2)}{E_0} \frac{P}{\sqrt{F}}.$$

This solution is quite near to the exact solution of Boussinesq for the round stamp (9).

In the case when the load is excentric, the problem may be solved similarly. We state the value of the tangens of the angle of slope of a square stamp under the action of a couple $\mathfrak{M}$ in the direction of one of the co-ordinate axes:

$$\operatorname{tg} \alpha = 0.60 \frac{(1 - \nu_0^2)}{a^3 E_0} \mathfrak{M}.$$

Observe that at the calculation of plates as well as further at the calculation of beams we neglect the friction between the plate (beam) and the foundation.

4. In the case of beams the formulae (4) become much simpler, since then we can neglect the squares and higher powers of β. Assuming that the load is symmetric with respect to the longitudinal axis x, we obtain the following formulae for the determination of the coefficients of even powers of x and y in the equation (3):

$$\left.\begin{aligned} &\text{for } v \neq 0,\ i \neq u;\ c_{2u,2v,2i,2j} = 0; \\ &\text{for } v \neq 0,\ i = u;\ c_{2u,2v,2i,2j} = \frac{4}{2v(2j - 2v + 1)}, \\ &\text{for } v = 0,\ i \neq u;\ c_{2u,2v,2i,2j} = \frac{4}{(2i - 2u)(2j + 1)}, \\ &\text{for } v = 0,\ i = u;\ c_{2u,2v,2i,2j} = \frac{4}{2j + 1}\left(\ln 2\alpha - d_{2u} + \frac{1}{2j + 1}\right), \end{aligned}\right\} \quad (6)$$

$$\text{where } d_{2u} = -(2u)! \sum_{m=1}^{m=2u} \frac{(-1)^m}{(2u - m)!\, m - m!}.$$

The values of $c_{2u+1,2v,2i+1,2j}$ (the coefficients of uneven powers of x) are determined also by the formulae (6), where $2u$ and $2i$ are to be replaced by $2u+1$ and $2i+1$ respectively.

A further simplification we obtain, if we use the condition of absolute rigidity of beams on an elastic foundation in the transversal direction. This condition is a consequence of the fact that the breadth of the beam is small; for such dimensions the factor of flexibility (7, 8) proves to be so small that the assumption of absolute rigidity is practically exact, as it is also the case when we use Winkler's hypothesis.

Assuming, thus, that the displacements under the beam in the transversal direction do not depend on y, we put the coefficients of all powers of y different from zero in the equation (3) equal to zero. According to the equations (6) this leads to a separable infinite system of equations

$$\sum_{j=0}^{\infty} \frac{a_{u,2j}}{2j - 2v + 1} = 0 \quad \left\{ \begin{array}{l} u = 0, 1, 2, 3, \ldots \\ v = 1, 2, 3, \ldots \end{array} \right. \quad (7)$$

the exact solution of which with respect to the coefficients a_u is ([4], [7])

$$a_{u,2j} = \frac{1 \cdot 3 \cdot 5 \ldots (2j-1)}{2 \cdot 4 \cdot 6 \ldots 2j} a_{u,0}. \tag{8}$$

It may be shown that in virtue of (8) the law of pressures on the foundation will be expressed by the formula

$$p(x, y) = \sum_{i=0}^{\infty} \frac{a_{i,0} x^i}{\sqrt{1-y^2}}, \tag{9}$$

which shows that the pressures in the transversal direction will have the form of Sadowsky's diagram for the infinite rigid strip ([9]).

For the mean pressures acting in a given cross-section we shall have

$$p(x) = \sum_{i=0}^{\infty} a_i x^i, \quad \text{where} \quad a_i = \frac{\pi}{2} a_{i,0}. \tag{9'}$$

The equation of displacements of the foundation in the case of a load symmetrical with respect to the middle of the beam takes the form

$$w(x) = \frac{4(1-\nu_0^2)\, b}{\pi E_0} \sum_{u=0}^{\infty} \left[\sum_{\substack{i=0 \\ i \neq u}}^{\infty} \frac{a_{2i}}{2i-2u} + (\ln 4\alpha - d_{2u})\, a_{2u} \right] x^{2u}. \tag{10}$$

In the case of an unsymmetrical load similar terms with $2u+1$ and $2i+1$ instead of $2u$ and $2i$ must be added.

The flexure equation of the beam in the case of an arbitrary load may be written (exactly or approximately) in the form of an infinite series which holds for the whole beam ([7]). In virtue of the identity of the deflexions of the beam and the displacements of the foundation under the beam $y(x) \equiv w(x)$, we equate the coefficients of equal powers of x in the deflexion equations of the beam $y = y(x)$ and the displacements equation of the foundation

$$w = w(x) \tag{10'}$$

Together with the equilibrium condition these equations form an infinite system of equations with respect to the unknowns a_i. A sufficient accuracy will be guaranteed, if we solve the shortened system with respect to the a_i from a_0 till a_{i_0} inclusively. The theory of such systems of equations was developed by L. Kantorovitch and V. Krylov ([10]).

Thus, for instance, in the case of a load consisting of a concentrated force P applied in the middle of the beam, we obtain the following equations of the shortened system:

$$\left.\begin{aligned}
&\sum_{i=0}^{5} \frac{a_{2i}}{2i+1} = \frac{P}{2a}, \\
&\sum_{\substack{i=0 \\ i \neq 1}}^{5} \left(\frac{1}{2i-2} - \frac{\varkappa_{2i}}{2\beta} \right) a_{2i} + \left(\ln 4\alpha - d_2 - \frac{\varkappa_2}{2\beta} \right) a_2 = -\frac{1}{2\beta} \left(\frac{Pt}{2a} + r_2 \right), \\
&\sum_{\substack{i=0 \\ i \neq u}}^{5} \frac{a_{2i}}{2i-2u} + (\ln 4\alpha - d_{2u})\, a_{2u} + \frac{\lambda_{2u-4}}{2u\beta}\, a_{2u-4} = -\frac{r_{2u}}{2u\beta}. \quad (u = 2, 3, 4, 5).
\end{aligned}\right\} \tag{11}$$

In these equations t is the factor of flexibility:

$$t = \frac{(1 - \nu_1^2)\,\pi E_0 b a^3}{2\,(1 - \nu_0^2)\,E_1 J}$$

($E_1 J$ is the rigidity of the beam, ν_1, Poisson's coefficient of the material of the beam),

$$\varkappa_{2i} = \frac{t}{(2i+1)\,(2i+2)}; \quad \lambda_{2u-4} = \frac{t}{(2u-3)\,(2u-2)\,(2u-1)};$$

$$r_{2u} = t\,\rho_{2u}\,\frac{P}{a}, \quad \rho_2 = -0.0185, \quad \rho_4 = -0.7963, \quad \rho_6 = 2.1943,$$

$$\rho_8 = -3.3384, \quad \rho_{10} = 1.7657.$$

All other cases of loads are solved in the same manner with the help of the system (11) in which the free terms are to be replaced by different expressions as it has been exposed in our paper on the calculation of beams under the conditions of the plane problem (7), where we give a table of the expressions of these terms for different loads. For unsymmetrical loads we must add to the system (11) another system with respect to the a_{2i+1} consisting of 5 equations and nearly analogous to the first.

5. The great practical importance of the proposed method of calculation of beams on an elastic foundation consists in that it gives a considerable reduction (as concerns flexing couples) of the excessive safety coefficient under the pillars of strip foundations as compared with the calculation under the conditions of the plane problem and in the spans of the same foundations as compared with calculations based on Winkler's hypothesis.

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PHYSICS

ON THE MECHANISM OF COBALT MAGNETIZATION

By M. J. SHIROBOKOV

(Communicated by A. F. Joffe, Member of the Academy, 16. VI. 1939)

F. Bloch (1) was the first to prove that domains in ferromagnetic crystals are separated by boundary layers in which there occurs a gradual change of the direction of magnetic moments. A more exact investigation of the picture of ferromagnetic crystal structure was made by L. Landau and E. Lifshitz (2) for the case of ideal single crystals with one direction of easiest magnetization. It has shown that in this case the distribution of magnetic moments changes almost in the whole crystal in only one direction which is perpendicular to that of easiest magnetization; thus, the domains must have the form of flat parallel layers.

In the present investigation these conceptions are worked out for the case when a constant magnetic field is applied to the crystal.

The distribution of magnetic moments in the crystal having one axis of easiest magnetization may be determined from Euler's equations for the following variation problem

$$\delta \int \left\{ \frac{1}{2} \alpha \left[(\nabla s_x)^2 + (\nabla s_y)^2 + (\nabla s_z)^2 \right] + \frac{1}{2} \beta \left(s_x^2 + s_y^2 \right) - \mathbf{H} \cdot \mathbf{S} \right\} dV = 0 \qquad (1)$$

on the condition $s_x^2 + s_y^2 + s_z^2 = s^2 = \text{const}$, where s_x, s_y, s_z are components of the magnetization vector $\mathbf{S}$ (the easiest magnetization direction coincides with the z-axis), ∇ is the gradient operator, $\mathbf{H}$ is the intensity of the magnetic field inside the crystal. The integral is taken over the whole crystal.

The expression

$$\frac{1}{2} \alpha \left[(\nabla s_x)^2 + (\nabla s_y)^2 + (\nabla s_z)^2 \right]$$

represents the energy per unit volume due, principally, to the gradient of the vector magnetization direction in the boundary layer, and

$$\frac{1}{2} \beta \left(s_x^2 + s_y^2 \right)$$

is the magnetic anisotropy energy per unit volume [α and β are constants; their definition see in (2)].

1. Case when field **H** is parallel to the axis of easiest magnetization

Let us assume that the mean value of the magnetization vector in the direction perpendicular to the domain's plane (x-axis) is equal to zero. Then it is possible to consider all the magnetic moments as lying in the parallel planes showing a fan-like distribution ($s_x = 0$, s_y, s_z — depend only upon the co-ordinate x). Denoting by θ the angle between the axis of easiest magnetization and the direction of the magnetization vector we shall have

$$s_y = s \cdot \sin\theta, \quad s_z = s \cdot \cos\theta.$$

Euler's equation of the variation problem (1) has the form

$$\left.\begin{aligned} \frac{\alpha}{\beta}\frac{d^2\theta}{dx^2} - \sin\theta\cos\theta - \lambda\sin\theta = 0, \\ \lambda = \frac{H}{\beta s}. \end{aligned}\right\} \qquad (2)$$

Let us find a periodic solution of Eq. (2) assuming that dividing of a crystal into domains has a periodic character. Furthermore, we must find such a solution in which with x changing by 2Δ angle θ would change by 2π. The period is assumed to be given in advance. Let us denote it as 2Δ where Δ is the thickness of a domain [approximately $\Delta = 3 \cdot 10^{-4}$; see references (1) and (2)].

An examination of Eq. (2) shows that the solution required throughout the interval of the change $\lambda\,(0 < \lambda < \infty)$ has the form

$$\cos\theta = \frac{\gamma\,\mathrm{sn}\,u + 1}{\mathrm{sn}\,u + \gamma}, \qquad (3)$$

where

$$u = -\sqrt{1+\lambda\gamma}\,\sqrt{\frac{\beta}{\alpha}}\,x, \qquad \gamma = \frac{c_1 - 1 + \sqrt{(c_1-1)^2 - 4\lambda^2}}{2\lambda}. \qquad (4)$$

sn u is Jacobi's elliptic function. The constant c_1 may be found from the condition

$$\sqrt{\frac{\beta}{\alpha}} \cdot 2\Delta = \int_0^{2\pi} \frac{d\theta}{\sqrt{c_1 - \cos^2\theta - 2\lambda\cos\theta}},$$

where the condition

$$c_1 > 2\lambda + 1$$

must be satisfied.

The solution of Eq. (3) for different values λ is graphically shown in Fig. 1.

It should be noted that the effective thickness δ of the boundary layer is about thousand times less than the thickness Δ of the domain, thus the scale of Fig. 1 in the vicinity of the domain boundary is too large.

It may be seen from Fig. 1 that with the change of value λ within the limits $0 \leqslant \lambda \leqslant 8e^{-\sqrt{\frac{\beta}{\alpha}}\Delta}$ $\left(\text{for cobalt } \sqrt{\frac{\beta}{\alpha}}\,\Delta \cong 10^3\right)$ there occurs a displacement of the domain boundaries, whereby within this interval practically all the domains orientated opposite the field are destroyed. During the process of boundary displacement the effective thickness of the boundary layer does practically not change. This process is expressed by the steep part of the magnetization curve in the weak fields. With further increase of the magnetic field there occurs a compression

of the boundary layers. This gives first a rapid bend in the magnetization curve followed by an asymptotic approach to the saturation magnetization. The boundary layers strongly resist compression, because it is connected with a sudden increase in the gradient of the distribution of magnetic moments and, consequently, in the energy of the boundary layer. Owing to this in the crystal always remain germs of domains orientated in any arbitrary direction with respect to the field. However,

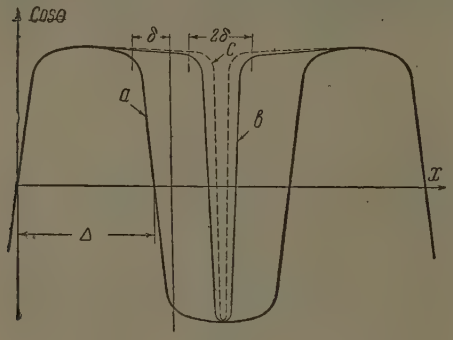

Fig. 1.

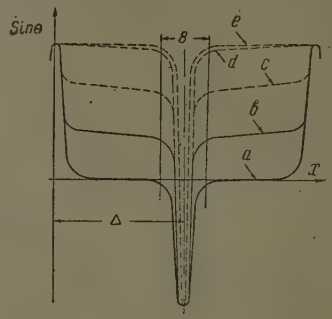

Fig. 2.

the displacement of the boundary layer due to the application of magnetic field does practically not change the gradient of distribution of the magnetic moments inside the layer. Consequently, the displacement occurs without any noticeable expenditure of work.

2. Case when H is perpendicular to the axis of easiest magnetization

Let the magnetic field **H** be directed along the y-axis. Then Euler's equation of the variation problem (1) will be

$$\left.\begin{aligned} \frac{a}{\beta}\frac{d^2\theta}{dx^2} - \sin\theta\cos\theta + \lambda\cos\theta = 0, \\ \lambda = \frac{H}{\beta s}. \end{aligned}\right\} \tag{5}$$

Examination of Eq. (5) shows that it is necessary to distinguish between the three intervals of values λ, the periodic solution in each of them having a special character, namely

1) $0 < \lambda < 1$;

$$\left.\begin{aligned} \sin\theta = \frac{\gamma_1 \operatorname{cn} u + 1}{\operatorname{cn} u + \gamma_1}, \\ u = \sqrt{\frac{\lambda}{\gamma_1}(\gamma_1^2 - 1)}\,\sqrt{\frac{\beta}{a}}\,x, \end{aligned}\right\} \tag{6}$$

$$\gamma_1 = \frac{c_1 + 1 + \sqrt{(c_1+1)^2 - 4\lambda^2}}{2\lambda}; \tag{7}$$

c_1 may be determined from the relation

$$\sqrt{\frac{\beta}{a}} \cdot 2\Delta = \int_0^{2\pi} \frac{d\theta}{\sqrt{c_1 + \sin^2\theta - 2\lambda\sin\theta}}, \tag{8}$$

where the condition

$$c_1 > \lambda^2$$

must be satisfied.

2) $1<\lambda<\sqrt{1+\left(\frac{\pi}{\sqrt{\beta/\alpha}\cdot\Delta}\right)^2}$.

With this interval the solution of Eq. (5) has also the form (6) with the value (7) for γ_1, however, condition

$$c_1 > 2\lambda - 1$$

has to be satisfied.

3) $\sqrt{1+\left(\frac{\pi}{\sqrt{\beta/\alpha}\cdot\Delta}\right)^2}<\lambda<\infty$;

$$\left.\begin{aligned} \sin\theta &= \frac{\gamma_1 \operatorname{sn} u + 1}{\operatorname{sn} u + \gamma_1}, \\ u &= \sqrt{\lambda\gamma_1 - 1}\,\sqrt{\frac{\beta}{\alpha}}\left(x+\frac{\Delta}{2}\right) \end{aligned}\right\} \qquad (9)$$

γ_1 has again the form (7); c_1 may be determined from (8), provided

$$c_1 > 2\lambda - 1.$$

The general character of these solutions is shown in Fig. 2.

Within the first interval there occurs rotation of the domains in the direction of the magnetic field. When $\lambda = 1$, the domains are entirely turned according to the field, magnetization being practically changed proportionally to λ. Only near $\lambda = 1$ the magnetization curve undergoes a sharp bend (but not a break, as it was assumed in the theories of Becker, Akulov, Hans).

The second interval is so small $(1 < \lambda < 1 + 5 \cdot 10^{-6})$ that it might be left without any consideration. The rotation of the domains is entirely completed, and there begins the process of compression of the boundary layers characteristic of the third interval.

It is seen from Fig. 2 that if the gradient of the magnetic moment distribution decreases in any boundary layer, it will certainly increase in the neighbouring boundary layer, and vice versa. Calculations show that the rotation of domains does not change the total energy of the boundary layers, provoking only a redistribution of energy between two successive boundary layers. Compression of the boundary layers, just as in the case of the magnetic field parallel to the axis of easiest magnetization, causes a rapid increase of the boundary layer energy. This process is expressed in the magnetization curve by an asymptotic approach to the saturation magnetization.

In order to get a good agreement with experimental data for the magnetization curves it is necessary to take into account the fourth degree member in the expression of the magnetic anisotropy energy. Investigations show that in this case the mechanism of magnetization remains without any change.

In conclusion I wish to express my thanks to Prof. A. G. Samoylovich for his guidance in my work.

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PHYSICS

ON THE DECAY OF ALKALI-HALOID PHOSPHORS ACTIVATED BY THALLIUM

By V. ANTONOV-ROMANOVSKY and G. KOCHERGIN

(Communicated by S. I. Wawilow, Member of the Academy, 17. VI. 1939)

In recent literature (1) the decay of alkali-haloid phosphors is usually supposed to take place according to a monomolecular reaction as opposed to a bimolecular one in the case of phosphors of the alkaline earths and zinc (2), i. e., it is assumed that during irradiation there takes place only excitation of the illumination centers and not ionization. This conclusion is based on the results of Bünger and Flechsig (3) who discovered an exponential decay law in certain specimens of KCl+Tl, and of Hecht (4) who did not observe increased conductivity in excited crystals of KCl+Tl. One of the present authors recently carried out measurements* of the decay in KCl+Tl which gave results contradicting this, the decay being found to take place according to a bimolecular reaction **. We carried out the following experiment in order to arrive at a final solution of the problem.

By means of an aluminium spark we obtained coloration in pure and activated crystals of KCl simultaneously (7). The specimens were then kept in darkness, and whilst it took 24 hours for the pure ones to become appreciably decoloured, in the case of the activated ones the time of decoloration was only a few hours. This is in good agreement with the circumstance that the time of decay of phosphorescence is of the order of an hour. The process is considerably accelerated in daylight, but the ratio of the decolaration times for the two cases remains approximately the same. The faster decoloration of the activated crystals points to the existence of a process accelerating «luminescence power exhaustion» whilst the parallel existing between decay and decoloration points to a direct connexion between them. It may therefore be affirmed that the monomolecular theory of alkali-haloid phosphors activated by Tl, which, by the way, has recently been developed in detail by Seitz (8), is essentially incorrect. Why decay nevertheless in certain cases takes place according to the exponential law, as was, for instance, obtained by Bünger and Flechsig, still remains to be explained. A number of suppositions may be advanced to explain this effect.

As early as in 1914 Kennard (9) showed that if we assume the existence of other electrons, besides photo-electrons, in an excited phosphor, the decay

* Unpublished.

** The first indications of this were given by Wawilow (5) some years ago. In addition Parfianovich (6) established that decay in the phosphor NaCl+Ni takes place according to a simple bimolecular reaction.

curve will approach more or less rapidly to an exponential form, the output of phosphorescence remaining unchanged. A second means of obtaining an exponential curve is to illumine the excited phosphors with «red» light, i. e. light with a wave-length longer than that of the exciting light. In this case acceleration of the «luminescence power exhaustion» and even extinction of the phosphorescence is often observed. If the «red» light influenced only the photo-electrons, extinction would not take place. There would only be an acceleration of the «luminescence power exhaustion». Consequently, it may be assumed that «red» light neutralizes the ionized centers (without radiation), and the photo-electrons should disappear simultaneously during this process. This is indicated by the fact that a phosphor which has been completely extinguished returns to the initial state in which it existed prior to excitation. If it is assumed that temperature extinction and extinction with foreign admixtures included into the substance of the phosphor are analogous with extinction with red light, we may, in the simplest case, write a differential equation connecting the change in the concentration of the ionized centers n with the time t, which will apply to all three sorts of extinction:

$$\frac{dn}{dt} = -pn^2 - \frac{1}{\tau} \qquad (1)$$

where p is proportional to the probalility of recombination and $\frac{1}{\tau}$ is probalility of extinction of an ionized center. Since the brightness of phosphorescence $I = pn^2$, it follows from (1) that:

$$I = \frac{pe^{-\frac{2t}{\tau}}}{\left\{\frac{1}{n_0} + p\tau\left(1 - e^{-\frac{t}{\tau}}\right)\right\}^2} \qquad (2)$$

When $t \gg \tau$ the curve becomes exponential:

$$I \cong \frac{pe^{-\frac{2t}{\tau}}}{\left\{\frac{1}{n_0} + p\tau\right\}^2} *.$$

If $\frac{1}{n_0} \gg p\tau$, we obtain from (2) that the decay is exponential from the start, i. e.

$$I \cong pn_0^2 e^{-\frac{2t}{\tau}}.$$

In distinction from the first case (Kennard's) the output of phosphorescence diminishes sharply.

Unfortunately, there are very few experimental data which might be used to verify the above theory. We may take the results of Byler ([10]) who measured the decay of the phosphor ZnS-Cu with various concentrations of Ni which acts as an extinguisher. His results in the form of curves with co-ordinates lg 1 and t give an undoubtedly exponential form for the phosphorescence decay curve with the maximum concentration of Ni (5.10^{-6}) (in the absence of Ni the decay curve is hyperbolic). We may use indirectly the results of Riehl ([11]) who found that in certain phosphors (ZnSCdS-Ag and ZnS at room temperature and in ZnS-Cu at higher ones) an increase in the emission of luminescence takes place when the intensity of the exciting light

* Although the result obtained is calculated for the case of extinction taking place according to a simple bimolecular reaction (the «luminescence power exhaustion» curve being a second order hyperbola if the extinction is zero), the basic condition of the gradual transition of the decay curve to an exponential in the presence of extinction nevertheless remains valid.

is increased. Riehl explained this result correctly in attributing it to the combined action of two factors—an increase in the rate of «luminescence power exhaustion» of the light as the intensity of excitation is increased and to temperature extinction. The effect observed by Riehl may be explained very simply on the bimolecular theory of decay of phosphorescence*. To be valid for Riehl's experimental conditions (the observations were made at the moment of excitation) expression (1) should be rewritten in the following form:

$$\frac{dn}{dt} = -pn^2 - \frac{1}{\tau}n + E = 0 \qquad (3)$$

where E is proportional to the intensity of the exciting light. Since $I = pn^2$ we obtain from (3) that the relative emission of phosphorescence:

$$\frac{I}{E} = \frac{(\sqrt{1 + 4\tau^2 pE} - 1)^2}{4\tau^2 pE}.$$

This formula is applicable only provided there is no fluorescence or any other transitory process. If this is also taken into account, we obtain a further, more general formula:

$$\frac{I}{E} = \frac{(\sqrt{1 + 4\tau^2 pkE} - 1)^2 + 4\tau^2 pk'E}{4\tau^2 pE}, \qquad k + k' = 1 \qquad (4)$$

where kE is the intensity of phosphorescence in the absence of extinction, $k'E$—the intensity of fluorescence, which is always proportional to the light intensity incident on the phosphor. Formula (4) is in good agreement with Riehl's experimental results if we take that in the absence of extinction the intensities of phosphorescence and fluorescence are equal ($k' = k$) and then choose the corresponding numerical values for $\tau^2 p$ (the value of which vary from one phosphor to another). This gives reason to suppose that the decay curve should be exponential in the case of temperature extinction**.

The following conclusion may be drawn from the results obtained. When the decay curve is hyperbolic, it can be concluded with great probability that the process of «luminescence power exhaustion» takes place according to a bimolecular reaction. The cases of exponential decay cannot be considered to demonstrate that the process is monomolecular and require further investigation.

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* This fact was known to Becquerel [12] as early as the end of the XIX century and follows automatically from the bimolecular theory.

** It should be mentioned that it is also possible that there are means of extinction which do not change the form of the decay curve.

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PHYSIQUE

MÉTHODE ABSOLUE DE MESURE DE LA CONSTANTE DIÉLECTRIQUE ET DES PERTES DANS LES LIQUIDES À ONDES DÉCIMÉTRIQUES

Par M. DIVILKOVSKY

(Présenté par L. I. Mandelstam, de l'Académie, le 19. VI. 1939)

1. Une méthode de mesure des pertes dans les liquides à haute fréquence à l'aide d'un thermomètre à réservoir sphérique, rempli du liquide étudié, a été déjà publiée par l'auteur et M. Filippoff (1). Le thermomètre était placé dans un champ électrique de haute fréquence, dont l'intensité était également mesurée par un thermomètre (2). Cette méthode ne permet pas de mesurer la constante diélectrique du liquide, qu'il faut supposer connue.

M. Filippoff a depuis mis au point une méthode de mesure simultanée des parties réelle et imaginaire de la constante diélectrique $\varepsilon = \varepsilon' - i\,\varepsilon''$ au moyen d'un thermomètre à réservoir en forme d'ellipsoïde de révolution.

L'auteur, dans une publication précédente, a exposé un calcul général de l'échauffement d'une sphère placée dans un champ alternatif homogène électrique ou magnétique (3); il y est démontré que la méthode thermométrique peut permettre de déceler l'échauffement de beaucoup de liquides diélectriques polaires ou, encore mieux, d'électrolytes, dans le champ magnétique à ondes décimétriques. Cela rend donc possible, en n'employant qu'un thermomètre sphérique, d'obtenir la seconde relation nécessaire pour la mesure simultanée de la constante diélectrique du liquide.

2. En effet, la puissance développée dans une sphère de rayon R, de perméabilité magnétique $\mu = 1$, placée dans un champ électrique ou magnétique homogène $E_0 e^{i\omega t}$ ou $H_0 e^{i\omega t}$ a la forme:

$$W_E = \frac{3}{2} E_0^2 R^3 \frac{\varepsilon''\omega}{(\varepsilon'+2)^2 + \varepsilon''^2}, \qquad (1)$$

$$W_M = \frac{\omega^3 \varepsilon''}{60c^2} H_0^2 R^5 \qquad (2)$$

c étant la vitesse de la lumière.

Mesurant l'échauffement ΔT de la sphère dans l'espace de temps τ, sachant le rayon R de la sphère et sa capacité thermique C, ainsi que l'intensité du champ, on obtient donc les valeurs de ε' et ε'' à l'aide de la relation:

$$W = AC\frac{\Delta T}{\tau},$$

A étant l'équivalent mécanique de la chaleur. Ces considérations simples doivent être soumises à une série de restrictions essentielles:

a) Les formules (1) et (2) ne sont exactes que dans le cas où la longueur d'onde dans la substance de la sphère $\left(\lambda' = \frac{\lambda_0}{\sqrt{\varepsilon'}}\right)$ et la «profondeur de pénétration» des champs par suite du skin-effet $\left(\delta = \frac{1}{\sqrt{2\pi}} \frac{\lambda_0}{\sqrt{\varepsilon''}}\right)$ sond grandes par rapport au rayon de la sphère, autrement dit, quand le champ dans le liquide est homogène. Si tel n'est pas le cas, on doit avoir recours à des formules plus complexes ([3]), ce qui ne change d'ailleurs rien en principe.

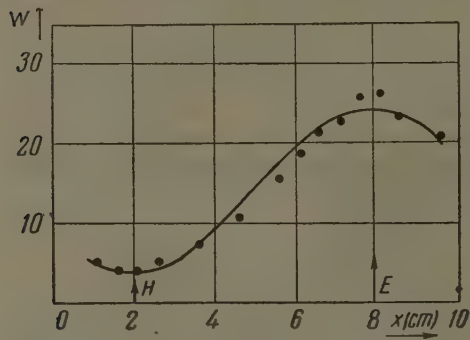

Fig. 1. Alcool méthylique, $\lambda_0 = 23.6$ cm.

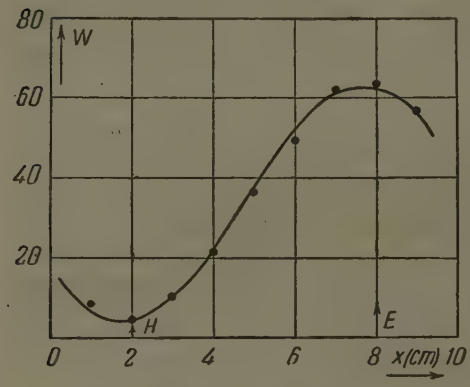

Fig. 2. Alcool éthylique, $\lambda_0 = 23.6$ cm.

b) L'enveloppe de verre ou de quartz du réservoir du thermomètre change quelque peu la valeur du champ électrique dans le liquide, n'influant pas toutefois sur son homogénéité. L'épaisseur des parois et leur constante diélectrique étant connues, on peut estimer la correction correspondante. Cette complication n'apparaît pas dans le cas du champ magnétique.

c) Les parois du réservoir et partiellement le capillaire du thermomètre absorbent une partie de la chaleur développée dans le liquide, ce qui cause une décroissance de la puissance observée. La correction correspondante peut être estimée avec une précision suffisante.

3. L'objet des expériences exposées ci-dessous était d'éprouver cette méthode aux plus courtes ondes possibles, encore obtenables à puissance suffisante (quelques dizaines de watts). Les conditions de travail ne nous permettaient pas de prendre toutes les précautions nécessaires pour une bonne précision des résultats; c'est pourquoi dans les chiffres obtenus la précision n'est que de 20 à 30%.

Les mesures étaient effectuées à l'aide de magnétrons à ondes fixes: $\lambda_0 = 23.6$ cm et $\lambda_0 = 18.4$ cm dans un système de fils parallèles (diamètre 4 mm, éloignement de 4 à 6 cm). L'intensité du champ de l'onde stationnaire était mesurée au moyen d'un thermomètre à mercure, fixé dans l'un des ventres du champ magnétique. Ce thermomètre avait été soigneusement calibré à l'onde 450 cm par la méthode exposée auparavant ([2]). L'absence d'ondes progressives était établie à l'aide du thermomètre avec toute la précision possible.

Les expériences étaient faites avec trois alcools: méthylique, éthylique et propylique, préalablement distillés, et avec un électrolyte—solution aqueuse de chlorure de potassium, de concentration 0.035 de la normale.

La température variait de 16 à 18° C. Les alcools étaient mesurés dans un même thermomètre de quartz, ayant les données suivantes: diamètre extérieur du réservoir 0.928 cm; épaisseur des parois du réservoir 0.012 cm; sensibilité 0.164, 0.171 et 0.194 degrés par millimètre du capillaire (respectivement pour les trois alcools).

Le thermomètre pour la mesure de l'électrolyte était de quartz, à diamètre extérieur du réservoir 1.018 cm, épaisseur des parois du réservoir 0.022 cm et sensibilité 0.625 degrés par millimètre du capillaire.

On voit dans les quatre figures l'échauffement observé dans les quatre substances étudiées, en fonction de la position du thermomètre le long des fils (unités arbi t raires). Les courbes pleines sont des sinusoïdes, calculées par la méthode des moindres carrés d'après les points observés.

Le rapport de l'échauffement au ventre des champs électrique et magnétique varie considérablement pour des liquides différents. Pour l'alcool·propylique ce rapport est grand (environ 25); c'est pourquoi la précision dans ce cas est la plus faible. L'électrolyte s'échauffe plus fortement dans le champ magnétique que dans le champ électrique.

4. Le tableau contient les résultats obtenus pour les alcools en valeurs de ε' et ε'', calculées en tenant compte de toutes les corrections mentionnées; la précision est estimée avec grande prudence. Les corrections thermiques sont de 10% en moyenne.

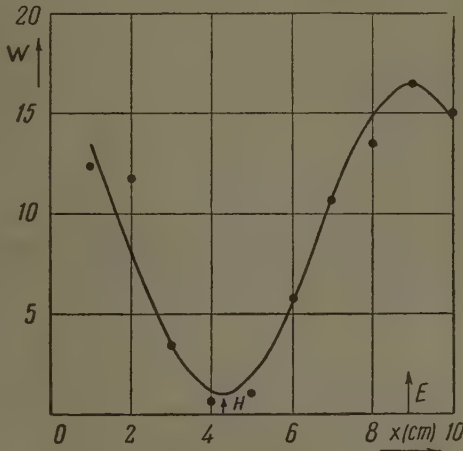

Fig. 3. Alcool propylique, λ_0=18.4 cm;

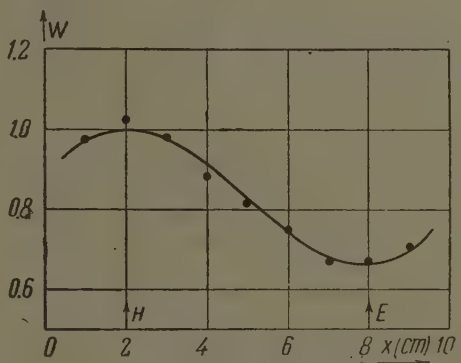

Fig. 4. Electrolyte, λ_0=23.6 cm.

On trouve à titre de comparaison à la fin du tableau les valeurs de ε' et ε'', mesurées par M. Filippoff à l'onde λ_0=443 cm par la méthode du thermomètre ellipsoïde ainsi que les valeurs tabulaires pour le cas statique.

On voit que malgré le peu de précision des mesures, la dispersion dans ce domaine de fréquences est bien prononcée pour l'alcool éthylique et surtout pour l'alcool propylique. Sous ce rapport, nos résultats sont en accord qualitatif avec ceux d'Ardenne, Groos et Otterbein (4) (alcools éthylique et méthylique), obtenus par la méthode ordinaire (méthode de Drude) et ceux de Mitsushima (5) (alcool propylique). Nos mesures ne permettent toutefois d'affirmer qu'il existe une dispersion sensible dans l'alcool méthylique à ces fréquences, bien qu'ils ne soient pas en contradiction avec les résultats des auteurs mentionnés, ainsi qu'avec ceux d'Esau et Bäz (6).

Tableau

Alcool méthylique				Alcool éthylique			Alcool propylique		
λ_0 (cm)	ε'	ε''	$\frac{\varepsilon''}{\nu}.10^7$	ε'	ε''	$\frac{\varepsilon''}{\nu}.10^7$	ε'	ε''	$\frac{\varepsilon''}{\nu}.10^7$
18.4	28.5±7	13.0±3	0.080	—	—	—	4.7±2	12.0±3	0.074
23.6	28.2±6	9.9±2	0.079	16.6±5	10.9±2.2	0.086	12.1±8.5	8.0±2	0.063
443	31.7	0.6	0.088	26	1.0	0.147	21.2	2.2	0.324
∞	31.2	—	—	26	—	—	22.2	—	—

Quant à l'électrolyte, les chiffres obtenus indiquent une forte croissance de la conductibilité par rapport à sa valeur statique, la constante diélectrique restant invariable. Vu l'importance de cette question et l'insuffisance du matériel à disposition, notre intention est de prolonger l'étude dans ce sens.

5. Nous avons donc démontré que cette méthode est applicable à la mesure absolue de la constante diélectrique et des pertes dans les liquides à très haute fréquence.

Les mesures relatives, qui n'exigent pas la connaissance de l'intensité du champ, peuvent être effectuées par cette méthode avec grande précision. Les valeurs absolues, qui dépendent du calibrage du thermomètre à mercure servant à mesurer l'intensité du champ et de l'exactitude de l'estimation des corrections thermiques, peuvent être obtenues avec une précision de 5 à 10%. Les limites d'application de notre méthode à des ondes encore plus courtes sont posées par les dimensions du thermomètre et la puissance nécessaire.

Notons encore que la forme géométrique simple de l'instrument (sphérique) et l'éloignement des électrodes permettent de calculer rigoureusement la distribution réelle des champs dans le liquide, distribution qui n'est pas en général homogène par suite du skin-effet et de la longueur d'onde. Cette circonstance est essentielle, car la «profondeur de pénétration» à ces fréquences dans les liquides étudiés est de l'ordre de 1—2 cm, ce dont il n'est pas tenu compte dans la plupart des autres méthodes.

Les mesures et le réglage des oscillateurs ont été effectués par l'auteur en collaboration avec S. M. Rytov et M. I. Filippoff.

Institut de Physique.
Académie des Sciences de l'URSS.

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BIOLOGISCHE PHYSIK

DIE ELEKTRISCHEN EIGENSCHAFTEN DES BLUTES UNTER DER WIRKUNG DER DEZIMETERWELLEN

Von N. N. MALOV

(Vorgelegt von S. I. Wawilow, Mitglied der Akademie, 17. VI. 1939)

Die Untersuchung der elektrischen Eigenschaften (Leitfähigkeit b und Dielektrizitätskonstante ε) des Blutes ist von grossem Interesse für die Elektromedizin.

Nach der Theorie von Dänzer (1) muss man im Blut eine Dispersion der elektrischen Eigenschaften erwarten. Dänzer betrachtet das Blut, als ein gutleitendes Elektrolyt (Plasma), in welchem die roten Blutkörperchen (gutleitende Plasma in einer dünnen dielektrischen Hülle) schwimmen.

Bei niederfrequenten Strömen ist der kapazitative Scheinwiderstand der Hülle sehr gross, und die Blutkörperchen nehmen fast keinen Teil im Prozesse der Stromführung.

Bei hohen Frequenzen spielt aber der Scheinwiderstand der Hülle keine merkliche Rolle; deswegen muss die hochfrequente Leitfähigkeit des Blutes zunehmen. Die äquivalente Dielektrizitätskonstante des Blutes ist auch frequenzabhängig: sie nimmt bei steigender Frequenz ab.

Sind die rote Blutkörperchen von der äusseren Plasma getrennt (z. B., mittels der Zentrifugierung), so kann man erwarten, dass die Plasma keine Dispersion, die Blutkörperchen aber eine sehr grosse Dispersion zeigen müssen. Wenn man die Hülle der zentrifugierten Blutkörperchen zerstört (z. B., mit der Essigsäure), so muss fast keine Dispersion beibehalten sein.

Der Gang der Dispersionskurve ist von der relativen Dicke der Hülle

$$\vartheta = \frac{R_1 - R_0}{R_0},$$

wo R_1 und R_0 den äusseren und inneren Durchmesser der Körperchen bedeuten, sowie auch von dem Verhältniss der Volumen der Körperchen v_K und des Blutes v_B

$$p = \frac{v_K}{v_B}$$

abhängig.

Die Messungen verschiedener Verfasser zeigen, dass für das Blut beträgt p etwa 0.3, für die zentrifugierte Blutkörperchen etwa 0.8—0.9. Der genaue ϑ-Wert ist unbekannt, man kann aber behaupten, dass $\vartheta \ll 1$ ist. Dänzer nimmt bei seinen Rechnungen $\vartheta = 0.002$.

Die nach dieser Theorie berechneten Werte von ε und $\frac{g}{g_0}$ (g_0 — die Leitfähigkeit bei ganz tiefen Frequenzen) sind in der Tabelle 1 angegeben.

Die elektrischen Eigenschaften des Blutes und seiner Bestandteile bei Meterwellen untersuchten Graul (2), Osswald (3) und der Verfasser (4). Die entsprechende Daten sind in der Tabelle 2 zusammengestellt.

Tabelle 1

Dispersion des Blutes nach Dänzer

Wellenlänge	$\vartheta=2\cdot10^{-3}$				$\vartheta=5\cdot10^{-3}$				$\vartheta=2\cdot10^{-2}$			
	$p=0.3$		$p=0.8$		$p=0.3$		$p=0.8$		$p=0.3$		$p=0.8$	
m	ε	g/g_0	ε	g/g_0	ε	g/g_0	ε	g/g_0	ε	g/g_0	ε	g/g_0
200	564	1	930	1	254	1	376	1	100	1	105	1
20	298	1.26	560	3.77	220	1.11	342	1.93	98	1	100	1
¼	93	1.47	115	6.07	100	1.41	108	4.72	87	1.10	86	1.72
2	84	1.50	88	6.15	82	1.46	84	5.20	77	1.20	71	2.64
0.2	80	1.50	80	6.15	75	1.49	67	5.35	69	1.24	52	2.85

Der Verfasser hat auch die Messungen bei Dezimeterwellen ($\lambda=65$ cm) durchgeführt. Als Generator diente ein Magnetron.

Die Anoden- und Heizspannung lieferten die Akkumulatoren. Der Elektromagnet wurde von einer leistungsfähigen Dynamo gespeist. Bei den Messungen wurde die Methode von Drude-Coolidge benutzt; die Theorie der Methode für die Messung der Objekte mit grosser Leitfähigkeit (ca. $5\cdot10^{-3}$ prakt. Einheiten) wurde schon früher entwickelt (5). Das Fehler der Messungen konnte 5—7% nicht übersteigen. Die Einzelheiten der Messungen werden an anderer Stelle betrachtet. Die Ergebnisse dieser Messungen sind in der Tabelle 2 gegeben.

Die Daten der Tabelle 2 zeigen, dass die Theorie von Dänzer in allem und ganzem richtig ist, indem der wahrscheinlichste ϑ-Wert etwa 10^{-2} beträgt.

Es ist von Interesse, dass die Leitfähigkeit der Plasma bei $\lambda=65$ cm abnimmt. Diese Abnahme kommt auch in den Leitfähigkeiten des Blutes und der Blutkörperchen zum Ausdruck; diese Leitfähigkeiten nehmen weniger zu als man nach der Theorie erwarten dürfte (nach der Theorie ist die Leitfähigkeit der Plasma frequenzunabhängig). Die Abnahme der Leitfähigkeit im Falle der Dezimeterwellen beobachtete der Verfasser auch bei konzentrierten wässrigen NaCl-Lösungen, die nach der Methode von Drude-Coolidge untersucht waren.

Tabelle 2

Messungen der Dispersion des Blutes

Wellenlänge	Mensch							
	Plasma		Blut		Rote Blutkörperchen			
					zentrifugiert		zerstört	
m	ε	g/g_0	ε	g/g_0	ε	g/g_0	ε	g/g_0
6.00—20.00	—	—	—	1.55	—	7.9	—	—
12.00	—	—	—	—	—	—	—	—
3.50	—	—	99	1.67	—	—	—	—
3.00	—	—	—	—	—	—	—	—
0.60	52	0.78	67	0.98	52	4.17	59	2.00

Wellenlänge	Hammel								Verfasser
	Plasma		Blut		Rote Blutkörperchen				
					zentrifugiert		zerstört		
m	ε	g/g_0	ε	g/g_0	ε	g/g_0	ε	g/g_0	
6.00—20.00	—	0.96	—	1.28	—	2.7	—	—	Graul
12.00	82	1.00	120	1.44	190	10.3	78	1.04	Osswald
3.50	95	0.98	—	—	109	3.58	85	1.40	Malov
3.00	82	1.00	78	1.44	—	—	—	—	Osswald
0.60	72	0.62	65	1.14	55	1.47	60	0.82	Malov

Ähnliche Resultate gaben auch die Messungen nach abgeänderter erster Methode von Drude. Da bei dieser Methode eine grosse Menge der Flüssigkeit nötig ist, wurden nur die NaCl-Lösungen untersucht.

Die Debye-Falkengagen'sche Theorie der Elektrolyten ist für diese konzentrierten Lösungen nicht anwendbar; eine Erklärung dieser Abnahme ist es schwer zu geben.

Zum Schluss ist es noch zu bemerken, dass die absoluten Messungen der Absorptionskoeffizienten der elektromagnetischen Wellen in konzentrierten wässrigen Elektrolytlösungen, die von Seeberger [6] ($\lambda = 14$ cm) und Elle [7] ($\lambda = 4$ cm) durchgeführt waren, die Leitfähigkeiten der Lösungen berechnen lassen; diese Werte sind kleiner, als die entsprechenden niederfrequenten Leitfähigkeiten.

Für eine genaue Untersuchung dieses Effektes muss man weitere Messungen der Leitfähigkeit der Elektrolyten bei Dezimeter- und Zentimeterwellen durchführen.

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CHEMISTRY

A NEW METHOD FOR THE SYNTHESIS OF AMINO-CARBOXYLIC ACIDS OF THE AROMATIC SERIES

By A. I. KIESBER

(Communicated by M. A. Iljinsky, Honorary Member of the Academy, 25.IV.1939)

The introduction of the carboxyl-group into aromatic compounds by Kolbe's reaction is well known for the case of hydroxy-derivatives of aromatic hydrocarbons. This process is used for the preparation of salicylic, hydroxy-naphtoic and different other acids. We have established that the process of direct carboxylation can as well be applied to aromatic amino-compounds.

The corresponding amino-carboxylic acids were obtained by heating aromatic amines with sodium bicarbonate and carbonate. In this way 1-amino-anthraquinone-carboxylic acid, 2-amino-anthraquinone-carboxylic acid, 2-naphtylamine-carboxylic acid and others have been obtained. The use of potassium carbonate or bicarbonate leads to the formation of other isomerides.

The preparation of 2-amino-anthraquinone-1-carboxylic acid is given as an example.

Ten parts by weight of sodium bicarbonate are carefully mixed with 10 parts of 2-amino-anthraquinone. The mixture is heated to 200° and this temperature is maintained for a few hours, whereupon it is boiled with 100—125 cm³ of water and filtered. The yellow-orange filtrate is acidified with hydrochloric acid and the reddish-brown 2-amino-anthraquinone-carboxylic acid is filtered off and washed with water until the wash water gives a neutral reaction.

Melting point 248—249° (according to Perkin and Spencer 250°*).
Sample 5.178 mg: 12.735 mg CO_2; 1.746 mg H_2O.
Sample 12.762 mg: 0.578 cm³ N (24.5°, 744 mm).
Found: C—66.96, H—3.77, N—5.09.
$C_{15}H_9O_4N$ requires C—67.38, H—3.40, N—5.24.
The investigation is being continued**.

Voroshilov's Institute of Organic Intermediates and Dyestuffs.
Moscow.

Received
25. IV. 1939.

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* Soc., **121**, 474.

** The reaction of the direct introduction of the carboxyl-group into aromatic aminoderivatives discovered by A. I. Kiesber, offers an indubitable interest and is the beginning of a series of investigations whose object will be to find adequate and simplified methods for the direct introduction of the carboxyl-group into aromatic compounds—hydroxy-, haloid-, nitro-, aminoderivatives and their substitutes.

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BIOCHEMISTRY

CHEMICAL STRUCTURE OF SUBSTANCES INDUCING POLYPLOIDY IN PLANTS

By A. SHMUCK and A. GUSSEVA

(Communicated by N. I. Vavilov, Member of the Academy, 19. V. 1939)

It has been shown by A. Blakeslee and A. Avery (1) that an irregular division of cell nuclei leading to polyploidy is called forth by the action of colchicine on plants.

One of the present authors (2) has reported another substance, acenaphthene, which is equal to colchicine in its power to affect cell division.

According to D. Kostoff (3), the cytological modifications induced by acenaphtene in plant cells are in all respects suggestive of cancerous tumors.

We have therefore much expected from establishing a correlation between the action of biologically active carbocyclic and heterocyclic compounds upon plants, on the one hand, and the action of carcinogenic substances upon animal organism, on the other.

For that purpose we have synthetized more than 100 different carbocyclic and heterocyclic compounds and tested their polyploidogenic action on plants.

In all cases the test for biological activity was conducted as follows. An aliquot of the substance to be tested was dissolved with sulphuric ether in a graduated flask and 1 mg of the solution was taken into a Petri dish on paper filter. After ether had volatilized the paper was wetted with water and seeds were sown upon it.

J. Cook and E. Kenneway (4) have found the carcinogenic hydrocarbons to lose their activity on the introduction of carboxyl-, hydroxyl-, nitro-, sulpho- or amino-groups. Windaus and Pennak (5) while trying the sulpho-, nitro-, amino-, tribromobenzopyrenes have failed to detect any carcinogenic activity in these derivatives of benzopyrene in face of the fact that benzopyrene itself is endowed with such activity.

Table 1 shows the biological action on wheat of the compounds synthesized by us against the carcinogenic activity of analogous derivatives of carcinogenic substances.

It will be apparent that the regularities established by various authors respecting the change in the activity of carcinogenic compounds on the introduction of certain groups recur also in the case of acenaphthene and naphthalene derivatives if their biological action on plants is considered. The single exception is nitronaphthalene which is very active with respect to plants while the nitroderivatives of carcinogenic compounds are reported in literature as inactive.

Table 1

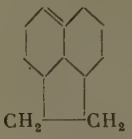
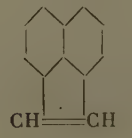
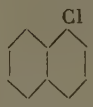
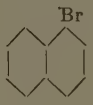
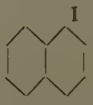
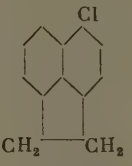
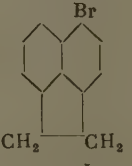
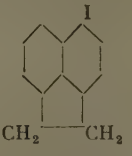
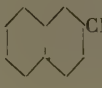
Preparation tested	Formula	Biological effect on wheat	Analogy to the respective carcinogenic substance
Acenaphthene		Active	
Acenaphthylene		Active	
Naphthalene		Very weak activity	
α-chloronaphthalene		Active	5-chlor-10-methyl-1.2-benzoanthracene, active
α-bromonaphthalene		Active	7-chlor-10-methyl-1.2-benzoanthracene, active [6]
α-iodonaphthalene		Active	
5-chloroacenaphthene		Active	
5-bromoacenaphthene		Active	
5-iodoacenaphthene		Inactive	
β-chloronaphthalene		Inactive	

Table 1 (continued)

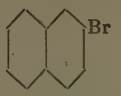
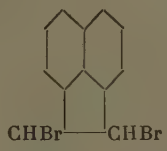
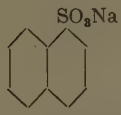
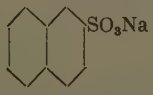
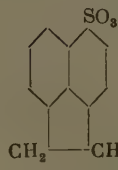
Preparation tested	Formula	Biological effect on wheat	Analogy to the respective carcinogenic substance
β-bromonaphthalene		Inactive	
β-iodonaphthalene		Inactive	
1.2-dibromoacenaphthene		Inactive	
x-tetrabromoacenaphthene		Inactive	Tribrombenzopyrene, inactive
p-dibromobenzene		Feebly active	
α-sulphonaphthalene (and salts)		Inactive	Sulphobenzopyrene and sulphomethylcholanthrene, both inactive
β-sulphonaphthalene (and salts)		Inactive	
5-sulphoacenaphthene (and salts)		Inactive	
α-naphthylamine		Inactive	
β-naphthylamine		Inactive	

Table 1 (continued)

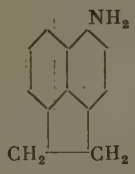
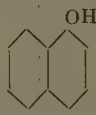
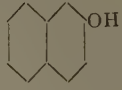
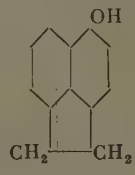
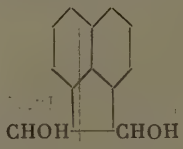
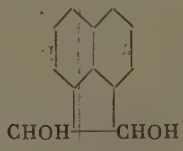
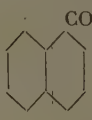
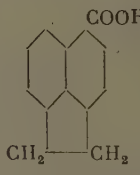
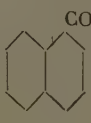
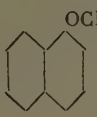
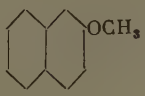
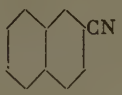
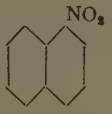
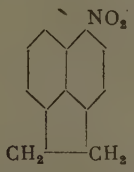
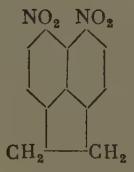
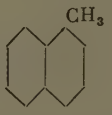
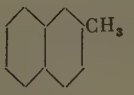
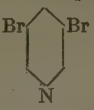
Preparation tested	Formula	Biological effect on wheat	Analogy to the respective carcinogenic substance
5-aminoacenaphthene		Inactive	Aminoderivatives of carcinogenic compounds, inactive
α-naphthol		Inactive	
β-naphthol		Inactive	
5-oxyacenaphthene		Inactive	Oxybenzopyrene and oxybenzoanthracene, both inactive
Acenaphthene-glycol-cis		Inactive	
Acenaphthene-glycol-trans		Inactive	
α-naphthoic acid and its salts		Inactive	Carboxyl derivatives of carcinogenic compounds, inactive
5-acenaphthene carbonic acid and its salts		Inactive	
Ethyl-α-naphthoate		Active	No data available

Table 1 (continued)

Preparation tested	Formula	Biological effect on wheat	Analogy to the respective carcinogenic substance
Methyl-α-naphthol ether		Active	
Methyl-β-naphthol ether		Inactive	
α-naphthylcyanid		Active	
β-naphthylcyanid		Inactive	
α-nitronaphthaline		Active	
5-nitroacenaphthene		Inactive	Nitroderivatives of carcinogenic compounds, inactive
5. 6-dinitroacenaphthene		Inactive	
α-methylnaphthaline		Active	5-methyl-benzoanthracene, active
β-methylnaphthaline		Inactive	6-methyl-benzoanthracene, very weak activity

Furthermore we have tried some heterocyclic compounds, and the biologically active among them with respect to plants have proved to be the chinolene and the 3.5-dibromopyridine 

It is worthy of note that the position of the groups is an important factor in the biological activity of the substances. Especially conspicuous is the difference between α- and β-derivatives of naphthaline, of which the first is endowed with incomparably higher biological activity.

The same is true of carcinogenic substances whose activity is also dependent upon the position of the groups (6).

The plants are not all equally responsive to the influence of biologically active substances (Table 2*).

Table 2

	Wheat	Barley	Peas	Vetch	Clover	Flax	Tobacco	*N. rustica*
Acenaphthene	+	+	—	—	—	—	+	+
Acenaphthylene	+	+	—	—	—	+	+	+
5-chloroacenaphthene	+	+	—	—	—	+	+	+
5-bromoacenaphthene	+	+	—	—	—	—	+	+
α-chloronaphthaline	+	+	—	—	—	—	—	—
α-bromonaphthaline	+	+	—	—	—	—	+	+
α-iodonaphthaline	+	+	—	—	—	+	+	+
α-dibrombenzene	+	+	—	—	—	—	—	—
3.5-dibromopyridine	+	+	+	+	+	+	+	+
Ethyl naphthoate	+	+	+	+	+	+	+	+
α-nitronaphthaline	+	+	+	+	+	+	+	+
Methyl naphthol ether	+	+	—	—	—	—	+	+

Note: + and — denote that the symptoms characteristic of active biological influence have been or have not been induced respectively.

From Table 2 it is evident that the most susceptible to the influence of biologically active substances are the cereals, while the leguminous plants are the most resistant.

Certain substances, however, as ethyl α-naphthoate, 3.5-dibromonaphthaline and α-nitronaphthaline, are equally active with regard to all plants tested. The carcinogenic substances are also known to exhibit a selective activity and only some of the animal species are affected by them (7).

Accordingly, the similarity between the biologically active and the carcinogenic substances lies not only in the formation of tumors and the cytological picture of abnormal cell division, but also in a number of other important characteristics.

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* Testing done by G. S. Ilyin.

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GEOLOGY

ON THE GEOLOGY OF THE CRYSTALLINE COMPLEX OF THE EASTERN MARGIN OF THE ALDAN PLATFORM

By J. K. DZEVANOVSKY

(Communicated by V. A. Obruchev, Member of the Academy, 8. VI. 1939)

Very little was known about the geological structure of the Chelasin river basin (the basin of the middle course of the Maya river) but superficially approached by former investigators (K. I. Bogdanovich—1895, V. N. Zverev—1913, A. A. Leontovich—1933—34). In the works of the above-mentioned authors the main stress was laid on other districts, adjacent to the one of Chelasin, whereas the latter received but rather scanty attention. Only in 1937 the first regional geological survey was carried out with A. I. Kuks' and my participation, and it has yielded a number of new and very interesting data on the geological structure of the region concerned. Being unable to render here a complete account of these materials, we shall dwell but on the question of age differentiation of the crystalline rocks of the region displaying a great variety within that area. This question assumes all the more importance because of the fact that the Chelasin basin lies at the easternmost point of the Aldan platform and the adjoining orogenic province each of them characterized by different igneous features. As we were able to find out, these can be summarized in the following table.

Cenozoic	Platform Orogenic province Tertiary	Hypabyssal alkaline rocks of the Aldan platform Andesites and basalts
Mesozoic	Upper Cretaceous Lower Cretaceous Upper Jurassic	Acid effusive rocks with their tuffs Granites of «Dzhugdzhur» type Porphyrites with their tuffs
Paleozoic	Upper Middle Lower	? Gabbro-diabases and diabases «Old-Stanovoi» gneisso-granites
Pre-Cambrian		Granites, gneisses and amphibolites

1. Pre-Cambrian (alleged Archean) complex.

Within the eastern margin of the platform the Pre-Cambrian crystalline complex, according to age, may be divided into two series. The first—to comprise biotitic gneisses, amphibolites and, particularly, widely developed

grey, sometimes brownish-grey biotite- and biotite-amphibole granites. To the second series pertain very monotonous, but none the less very characteristic flesh-red alaskites intruding rocks of the first, more ancient group. Thick beds of crystalline schists, characteristic of the middle parts of the platform, are absent here, the above-mentioned granites alone attaining here predominance.

The rocks of the entire complex are undoubtedly Pre-Cambrian in age, since within the area investigated they are overlain by faunistically characterized Lower Cambrian beds.

The middle portion of the Chelasin basin consists of the Pre-Cambrian rocks forming here the easternmost point of the platform. In the more northern, eastern and southern directions they disappear beneath sedimentary rocks of the Lower Cambrian, however, toward the west they extend in the shape of a continuous belt across the middle part of the basin of the Vatanga and Maymakan rivers (1), merging farther with the Pre-Cambrian middle portions of the platform.

2. Lower Paleozoic (Caledonian) gneisso-granites.

This group includes within the limits of the investigated region fine-grained yellowish-grey gneissoid granites, referable to the so-called «Old-Stanovoi» gneisso-granites of D. S. Korzhinsky. These rocks consist of oligoclase, microcline and microcline-perthite, quartz, biotitic and accessory minerals, the sharp prevalence of oligoclase over potash feldspar being a very characteristic feature of theirs. One of such characters is the gneissoid aspect of these granites due to their protoclastic texture. According to D. S. Korzhinsky, the age of the gneisso-granites is conventionally determined as Proterozoic, and their occurrence within the platform is confined to the zone of the Proterozoic «Old-Stanovoi» orogeny, extending over its southern border [(2) p. 193—198]. In 1933—34 A. A. Leontovich revealed a clearly intrusive contact of gneisso-granites with Lower Cambrian deposits of the Ignikan river valley [(1) p. 22)] and V. I. Serpukhov found in 1936 pebbles of these rocks in the Upper Carboniferous conglomerates of the upper reaches of Maya. Thus, the age of the «Old-Stanovoi» gneisso-granites may be considered at the present as established, and to be assigned as Caledonian.

3. The basic rocks of Middle Paleozoic (D_3—C_1).

The Pre-Cambrian and overlying sedimentary Lower Cambrian rocks of the region under description are intruded with very monotonous gabbro-diabases and diabases, ranging widely within the area of the right bank of Aldan. Here they occur throughout in identical conditions of deposition as dykes, or forming small sills in the Cambrian beds. The composition of these rocks is likewise very uniform. Their principal mineral constituents are: the basic plagioclase, pyroxene (usually augite), often replaced by uralite hornblende, and accessory minerals. The following considerations have induced us to determine their age as Middle Paleozoic.

In the described region gabbro-diabases, cutting through the Pre-Cambrian and Cambrian, are in their turn intruded with Mesozoic (Cr_1) granites. In the Allakh-Yuna district it is possible to determine their age more exactly, since here the gabbro-diabases break through the Cambrian, Upper Silurian and Devonian, while they are totally absent in Permo-Carboniferous deposits (3).

4. The Alpine magmatic complex.

From the table given above it follows that during the Mesozoic on the territory of the region under description proceeded the formation of rather varied magmatic rocks which terminated quite recently.

Depending upon the conditions of formation, two principal groups of rocks may be distinguished, intrusive and effusive ones, and in our descrip-

tion we shall follow this classification. Such a mode of description, though not conforming to the chronological succession of separate components of the entire complex, is still for many reasons the most appropriate one.

Let us begin our description with the group of effusive rocks.

All of the southern part of the Chelasin basin, occupying an area of 600 km², is composed of most diversified effusive rocks forming at this place a complex cover of multiple stratification. It comprises the following series (in ascending order):

Series I. Uniform beds of dark greenish-grey, considerably decomposed pyroxene porphyrites with a solid fine-grained base, and diminutive feldspathic and pyroxene phenocrysts. The lower portion includes a sheet of agglomerate tuffs of dark brown and violet-red colour, about 30 m thick, with fragments of porphyrites.

Thickness of the series is 130—150 m.

Series II. Overlying with a sharp angular unconformity the rocks of series I. Consists of rocks of alternating acidity. The lower horizons are represented by albitophyres, quartz porphyries, replaced higher up by quartz syenite porphyries, dacite porphyries, diorite and andesite porphyrites. The rocks are tinted grey, violet-grey, yellowish-white and greenish.

Thickness of the series is about 270 m.

Series III. Composed of basic dark coloured rocks constituted of basalts, vitroclastic tuffs of acid effusive rocks and basalts, albitophyres (about 5 m thick) and andesites. Reposing on the eroded surface of the underlying series.

Thickness of the series is about 150 m.

The aggregate thickness of the entire beds under description is equal to about 550—570 m.

Rocks of the I series are steeply dislocated and cut through by intrusions of Lower Cretaceous granites of the «Dzhugdzhur» type (after K. I. Bogdanovich). On the top of them, as already noted, are lying with sharp angular unconformity effusive rocks of series II, in some places of the region covered with the most recent andesite-basalts (series III). The latter, forming small isolated patches, are lying on hypsometrically different levels.

The above-described series of the igneous beds are referred to a given age provisorily, since the materials gathered within the region concerned permit of no grounded classification. We are therefore bound to use data from adjacent or geologically closely related regions as a basis for the arrangement adopted in the summarized table.

The lower porphyrite series we refer, according to the time of formation, to the Upper Jurassic for the reason that at the time of intrusion of the Lower Cretaceous Dzhugdzhur granites it had already existed, and was, apparently, involved in the same Upper Jurassic folding.

The effusive rocks of series II are referred by us to Upper Cretaceous since their vein material is, according to K. I. Bogdanovich, «obviously intersecting the Dzhugdzhur granitite beds» [(4), p. 44], and besides, according to A. I. Kuks, containing in their lowermost portions enormous blocks of the above-mentioned granites. Finally, the andesite basalts of the upper series seem to us to refer to the Tertiary time, this standing in no contradiction to statements of other explorers.

Among the intrusive rocks within the area of the described region a wide range of distribution exhibit but the Lower Cretaceous granites of 2 phases of injection. The former includes intrusions of biotitic and biotite-hornblendic granites of the Dzhugdzhur type, and the latter—dykes of very interesting micro-pegmatitic granites, described by K. I. Bogdanovich under the name of «microperthitic granites».

The intrusions of Dzhugdzhur granites form either batholiths or small stocks, passing from the orogenic province into the platform area. They are distinguished by good differentiation from biotitic and biotite-hornblendic granites in the middle portions of the massifs up to the grandiorite and quartz-diorites in their marginal parts. As the most acid varieties produced from very acid residual magma are to be recognized micropegmatitic granites, intruded into fissures already after the cooling of the rock masses of the Dzhugdzhur granites. The age of the two granitic varieties is provisorily determined by us as Lower Cretaceous, since the great majority of Mesozoic granites from the north-east belong exactly to that age. From data directly related to the age of granites herein described we should mention observations carried out by K. I. Bogdanovich, indicating that Dzhugdzhur granites are of younger age than the Middle Jurassic, but older than «the beds with plant imprints of the gulf of Uda whose conglomerates are showing absolute prevalence of the Dzhugdzhur type granite» [(4), p. 45].

All the rocks described refer to the orogenic type, their appearance being confined to and connected with the region of Alpine folds. Within the platform area, probably, simultaneously with the effusion in the orogenic province of andesite-basalts, was proceeding the formation of alkaline hypabyssal rocks of the Aldan petrographic province, which produced here small dykes of interstratified intrusions in horizontally lying beds of the Lower Cambrian. Among the rocks of this group we were able to identify quartz syenite-porphyries, syenite-porphyries, and, particularly, widely developed in the central parts of the platform bostonite-porphyries under the above-mentioned conditions of deposition. Leaving aside the description of all these rocks, we shall consider but their relations with formations indicated above, which is of great value for determination of their age.

Apart from the breaking through by the above-mentioned rocks of the Pre-Cambrian and Lower Cambrian deposits, syenite-porphyry dykes intrude into lower porphyrite series of the igneous beds (I_3), and the bostonite-porphyries cleave the Lower Cretaceous granites as well. Then, as already noted, among effusive rocks of series II, provisorily assigned to the Upper Cretaceous, we have met with quartz syenite-porphyries, according to their petrographic composition standing very close to similar rocks from other parts of the platform. Unfortunately, we were unable to find out whether they form at this place a rock sheet or an interstratified intrusion, this extending their age from the Upper Cretaceous to the Tertiary. Certain geological data still warrant the hazard of assumption that the alkaline rocks of the Chelasin basin are rather Tertiary in age. J. A. Bilibin, too, is inclining to this view, when pointing out «the Tertiary, possibly, Cretaceous age» [(5), p. 413] of the alkaline rocks of the Aldan platform.

Gold Prospecting Trust.
Leningrad.

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MINERALOGY

NEW DATA ON THE CHEMICAL COMPOSITION OF «GOLD CUPRIDE»

By M. P. LOZHECHKIN

(Communicated by A. E. Fersman, Member of the Academy, 5. VI. 1939)

The mineral described here was discovered in the Carabash Gold-ore layers (Soimon valley, S. Urals) and was first described by A. V. Nikolaev ([6]). On account of its copper-reddish colour and high copper content in the ligature, he called the mineral gold cupride. Later K. A. Nenadkevitch([5]) analyzed it chemically and found that there was 20.4 per cent Cu and 4.5 per cent Ag present in the gold. On the basis of these data W. I. Vernadsky ([1])

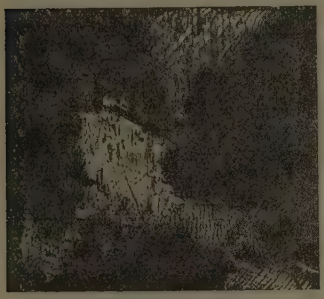

Fig. 1.

Fig. 2.

stated that «of all the physically homogeneous golds this is the richest in copper», and expressed the assumption that gold cupride is a solid solution Cu—Au. In 1935 M. P. Lozhechkin ([4]) established that it is physically non-homogeneous, and is a fine mechanical mixture of the two components.

A mineralographic study showed that greenish-yellow ingrowths of various size and shape can be observed on the yellowish-red background, which corresponds to gold cupride. These ingrowths may be suspected as being pure or sterling gold. Figs. 1, 2 illustrate the nature of distribution of these ingrowths and show a microstructure characteristic for decomposed solid solutions. The most usual structures are the lattice structure (Fig. 1) and the lamellar structure (Fig. 2).

Gold cupride amalgamates more weakly and etches more strongly than sterling gold. In polarized light the first component which shows slight anisotropy is composed of separate grains of rhombic section, while the second is entirely isotropic. The reflectivity of the components was studied

by means of Inostrantzev's comparison chamber. The samples studied are increasingly reflective in the order 1) native copper, 2) gold cupride, 3) sterling ingrowths and gold from Stepnyak and Kolima, 4) Tielgin gold (its test equals 96—98.5) and chemically pure gold. A study of polished surfaces under the Endelle-Samsonov heating microscope showed that gold cupride begins to oxidize at 260°. After heating at 350° for 3 hours the gold powder turned completely black, having become covered with thin films of tenorite, which was then dissolved in HCl, after which the metal turned to its usual colour (reddish).

Fig. 3.

The data given above show that the formula of «gold cupride» cannot be deduced from a total chemical analysis, for this gives only the average composition of a mixture of two minerals.

In trying to determine the chemical composition of both minerals we met with the fact that it is utterly impossible to separate them. For this reason we made X-ray investigations. Besides this, for control sake, the quantities of both minerals were estimated under the microscope with a pushintegrator, and a chemical analysis was made. Gold plates of the same sample were analyzed chemically, mineralographically and by X-rays. It was especially interesting to make these investigations, because experimental workers ([3]) established complete miscibility of Cu—Au in liquid and solid states, and if the temperature is lowered (about 400°) this mixture may decompose into two chemical compounds (CuAu and Cu_3Au), which are in turn capable of giving solid solutions, within certain limits, with pure components. For CuAu these limits are 42.5—70 per cent (at.) Au, and for Cu_3Au—22—40 per cent (at.) Au. Since the types and parameters of the crystal lattices of these compounds and of their alloys have been determined roentgenographically by a number of investigators, the X-ray analysis undertaken by us had its purpose in finding the chemical composition of both of our native minerals and in establishing the kind of bond between the elements in their composition. (Analogously the presence of the chemical compound CuAu seemed fully possible in our case also.)

The results of X-ray investigation (the analysis was performed at the Institute for Mineral Raw Materials by Lyamina) showed that Carabash gold is really a mixture of two components. One of them is gold with a constant cubic lattice $a=4.06$ Å, and the other is a solid solution Cu—Au, containing 60 per cent (at.) Cu ($a=3.83$ Å). The second component predominates greatly in the sample, since its lines are the most intense ones; however, the cubic lattice shows that we have here not a chemical compound, but a solid solution, because artificial cuproauride (CuAu) according to J. H. Johansson ([2]) etc. has a tetragonal lattice.

As to the first component, it is probably entirely free of Cu admixtures, but contains Ag. In any case the quantity of Cu in it cannot be above 6 per cent (at.), this value corresponds to a reduction in the parameter of the lattice of pure gold (4.07 Å) of 0.01 Å. However, just as great a deflection may be due to error in determining the constant lattice.

Below we give the chemical analyses of Carabash «gold cupride» which is a mixture of the two components described above, and also the calculation for the minerals (table).[1]

	I		II		III	Atomic equiv.	Cu_3Au_2	$AgAu_4$
	1	2	1	2				
Au	74.33	74.92	64.72	74.95	74.94	3 800	2 153	1 647
Ag	4.49	4.53	3.92	4.53	4.53	411	—	411
Cu	20.39	20.55	17.72	20.52	20.53	3 229	3 229	—
Undissolved residue	0.26	—	12.80	—	—	—	63.0*	37.0*
Total	99.47 %	100%	99.16%	100%	100%	—	64.0**	36.0**

Note: I—analysis 1911 (2); II—analysis 1935 (4); III—average of I and II. * Calculated from analysis (in weight %); ** counted in polished surfaces (in weight %).

In calculating the atomic equivalents for the minerals the composition of the gold cupride was inferred from the X-ray data; all the silver was supposed to be combined in the sterling component, on the following reasoning*: silver and gold are miscible within very wide limits, while for Ag—Cu mixtures these limits are quite narrow. Besides the data of a great number of analyses of Carabash «gold cupride» (tests of gold alloy laboratories) show that the Cu in it decreases as the Ag increases. Finally, the quantity of Ag in the sample in which the sterling component was observed in small quantity and was not shown on the powdergrams (Fig. 3), was equal to only 2 per cent, i. e., considerably less than in the first sample.

Thus, there is 63 per cent gold cupride and 37 per cent gold argentide in the composition of Carabash «gold cupride». The high Au : Ag ratio in the second component distinguishes it considerably from electrum and corresponds to an Ag content in it of 12 per cent (by weight).

On the basis of these studies the composition of native gold cupride can be considered to correspond to the formula Cu_3Au_2, which corresponds to a Cu content in it of 32.5 per cent (by weight), as was supposed before. In structure it differs from artificial cuproauride (CuAu) in its cubic lattice, and in composition it takes an intermediate position between the latter and tricuproauride (Cu_3Au). Of course in view of the fact that the mineral is not a chemical compound, this formula is empiric and approximate, because stoichiometric ratios are not necessary in a solid solution.

Nevertheless it was interesting to establish the fluctuation limits of the ratio Au : Cu, and this was done by X-ray analyzing other samples.

The two new powdergrams show the variation of the cubic lattice parameter of gold cupride. On one of them there are visible traces of gold argentide lines, and on the other they are absent altogether. Calculations of the parameters according to the first powdergram give $a = 3.91$ Å, and according to the second $a = 3.93$ Å.

The second powdergram (Fig. 3) was taken of a standard of chemically pure gold, and the displacement of gold cupride lines in relation to the standard can clearly be seen on it.

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* As a result of the identity of the lattice parameters of gold and silver (4.07 Å) it is impossible to find the latter by X-ray analysis.

Thus, the variation of the lattice parameter for gold cupride (from 3.83 to 3.93 Å) in different samples shows that the Cu content in the mineral varies comparatively little: from 56 to 60 per cent (at.).

However, lack of a sufficient quantity of studied samples makes it impossible to restrict the fluctuation limits to the above figures. Moreover, there are grounds to assume that these limits should be widened in both directions. Thus, making use of analyses of Carabash «gold cupride» (data of the gold alloy laboratory) we see that its composition varies within considerable limits. Taking extreme figures we get: 1) Au=51.9; Ag=1.1; Cu=47.0; 2) Au=87.2; Ag=8.8; Cu=4.0.

Recalculating these data to atomic equivalents and taking the composition of gold argentide in accordance with the data obtained above ($AgAu_4$) we get that the Cu content in the composition of gold cupride in the first analysis was 33 per cent (at.) and in the second 76.9 per cent (at.).

Hence fluctuations in the composition of gold cupride approximately from Cu_2Au_3 to Cu_3Au seem quite possible.

Thus, the «gold cupride» of the Carabash layer is not a homogeneous mineral but consists of two components: gold argentide and gold cupride. With regard to the latter an extremely high copper content [56—60 or possibly 33—77 per cent (at.)] should be noted and from this standpoint it is well to call it a new mineral just like electrum, leaving the name gold cupride only for varieties which contain copper in more or less usual quantities. It is difficult to agree with the fact that a mineral which oxidizes at so low a temperature (270°) should bear the name of gold, a noble metal. It is most natural to call it cuproauride, since artificial gold cupride has already received that name.

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MINERALOGY

ZONAL DISTRIBUTION OF ULTRA-BASITES OF THE CAUCASUS RANGE

By N. E. EFREMOV

(Communicated by A. N. Zavaritzky, Member of the Academy. 17. VI. 1939)

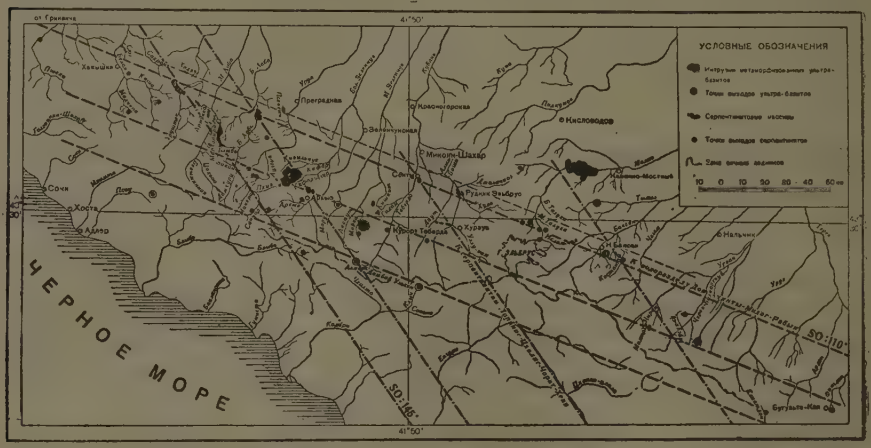
The Caucasian ultra-basites invite special and justified interest. The works carried out by the Kharkov Scientific Research Institute for Refractory Materials on the serpentine samples from the Caucasian beds have proved this new kind of raw material to be of great industrial value ([1],[6]).

Ultra-basites, for the most part represented by products of their metamorphization, i. e., serpentines, attain relatively great development in the Caucasus, having been fixed in the regions of Krasnodar, Karachai, Kabardino-Balkaria, Southern Ossetia, Northern Ossetia, Abkhazia and Imeritia. They are ranging within the area limited by 42°00′—44°15′ N. lat. and 57°15′—62°15′ E. long*. Over 60 massifs have been registered by me on the above-mentioned area. Their outcrops are known throughout the river basins: Belaya, Khodz, Malaya and Bolshaya Laba, Urup, Maly and Bolshoi Zelenchuk, Kuban, Teberda, Khudes, Daut, Malka, Baksan, Urvan, Urukh, Ardon, Shakhe, Mzymzy, Bzybi, Chkhalty, Kador, Kura. The massifs of the ultra-basic rocks of Caucasus are arranged in a series of interrupted ridges, roughly parallel to the axial part of the range. The position of these ridges is subject to well marked regularity which has found adequate expression in the term «the Serpentine Belt of Caucasus».

A chemical, mineralogical and petrographic study of the ultra-basic rocks of the Caucasus range allows of identifying rather varied components of the mother rocks which had produced the Caucasian serpentines. According to my investigations, such were: saxonites, dunites, lherzolites, cortlandites, wehrlites, biotitic peridotites, various pyroxenites, sometimes represented by monomineral, monoclinic pyroxenes and hornblendites. The rôle of pyroxenites and hornblendites is small. The latest data obtained by me show that apart from prevailing saxonites an important part was played by dunite rocks as well which, like lherzolites, fully deserve to stand next to saxonites. The reasons for such a great variety of serpentine mother rocks seem to me to be partly due to the assimilation of surrounding rocks, which has led to local changes in the chemism of the magma. Where the magma had intruded into and assimilated more ancient limestones, are traceable, as a rule, assemblages of, sometimes even isolated, monoclinic pyroxenes (Zagedan, Damkhurz, Kizylchuk and others). From general geological

* Map on a scale 1 : 210 000.

data, as well as mineralogic-petrographic studies of ultra-basites, it should be stated that, according to my interpretations (see map), outcrops of serpentine intrusions fit in well with several zones which have a parallel strike south-eastwards SO:110°*, and are in their turn rather roughly parallel to the axis of the range. It is noteworthy that the directions of the valleys of the passes at the upper reaches of the majority of the most important water systems of the northern and southern slopes of the Caucasian range likewise



extend in directions conforming to those constructed by me. I am differentiating the following four principal zones.

1st, main zone—Tkhach-Beden-Beskes-Senty-Khudes-Surkh-Islam-Chat-Kyugen-bay-Kestanty.

2nd zone—Urushten-Markopidge-Bzyb, intermediate between the 1st and 3rd zones.

3rd zone—whose imaginary axis runs 20 km south of the first and comprises the massifs: Zakan-Zagedan-Kizylchuk-Kjafar-Agur-Gidam-Khatipar-Uchkulan-Karachai-Aush-Daut-Mizhirgi-Chiran, Musukh and Sukan.

4th zone—whose axis passes at about 40 km south of the first zone, and to which I refer the massifs Bzyb, Aibgin, Damkhurz, Mamkhurz, Sanchar, Malo-Markinsky**, Verkhne-Dautsky, Alibek-Ulgensky, Klych and Kliat-Donsky.

In summarizing the results of my explorations, I arrive at a conclusion that the following rocks had yielded through metamorphization the serpentines of Caucasus:

for the 1st zone—saxonites and dunites
for the 2nd zone—mainly saxonites
for the 3rd zone—saxonites, lherzolites, dunites
for the 4th zone—lherzolites, wehrlites, cortlandites, saxonites and dunites.

From above the 1st zone are known dunites (Beloretchensky massif), below the 4th (the southern slope of the range)—saxonites of Lopanis Tzkhali,

* This direction was first marked by P. I. Lebedev (2) for the serpentine massifs Teberda-Tkhach and Daut-Abishiry-Ahuby.

** Malo-Markinsky and Verkhne-Dautsky massifs present serpentinized cortlandites. The Aibginsky massif is typically apowehrlite.

Choratkhevi, Zaraguli and others. With the data thus far obtained it does not seem necessary to separate the remaining three zones. It may be, however, safe to advance the contention that the serpentines of the zone Beloretchensky-Syug-Psyekench-Alyk-Bashi, lying to the north of the main zone, are for the most part composed of apodunites with accessory development of apocortlandites. Some distance away lie thick intrusive rocks of ultra-basites of Malka-Khasauta quite important from a practical standpoint. Alongside of aposaxonitic serpentines, widely developed at this place, I have identified here during my preliminary investigations areas with apolherzolites, apodunites, and, possibly, apowehrlites. The data available point to the existence of a certain regularity in their occurrence. This is manifested in the growing importance of rhombic and monoclinic pyroxenes and amphiboles within the rocks arranged in closer proximity to the axial part of the range. The inverse relation is observed in regard to olivine which has wholly superseded the rhombic pyroxene in the massifs of the more northern zones. Still another regularity becomes manifest when the location of the outcrops of ultra-basites is being examined. It may be readily seen from the map showing the range of the serpentine massifs. The lines with an azimuth of strike SO: 145° correspond to the highest degree of density of exposures of the massifs. Three lines are particularly distinct. The first for the massifs: Tkhach, Urushten, Magish-Markopidge Zakan, Zagedan, Mamkhurz, Sanchar and Verkhne-Labinsky. The second one for Beden, Nakhshir, Kizylchuk-Kyafar-Agur and Alibek- Ulgen. The third—for Malka, Tyzyl, Musukh, Sukan, Kliat-Donsky etc.

Thus, the link* of ultra-basite intrusions of the Caucasus with two line-systems is clearly brought forth—one with an azimuth of strike SO:110° and the other—SO:145°. As to the questions of the age of Caucasian ultra-basites, it should be noted that the data thus far obtained confirm the suggestion formerly advanced by the author that these rock varieties are of different age. True enough, we have not yet reached the ultimate solution of the question as to each separate massif. However, it can be reliably stated that intrusions of the most important groups of massifs should be classed among the early or, perhaps, the middle-Variscian intrusive phase (Zakan-Magish-Zagedan-Kyafar-Agur-Kizylchuk-Ekhresku, etc.), or to the Upper Paleozoic—Lower Mesozoic intrusive phase (Beden - Khudes-Senty etc.).

Apparently, separate intrusions are more ancient, i. e., Caledonian, or even Pre-Cambrian (Ossetia, Balkaria, upper reaches of Daut, etc.), but their share in the general volume is rather insignificant.

In this connexion, it should be noted that intrusions of ultra-basites of the Urals, according to Zavaritzky([3]), occurred during the Devonian and post-Lower-Carboniferous and the main bulk of basic and ultra-basic intrusions in Kazakhstan, according to N. G. Kassin([4]), are confined to the Upper Silurian orogenic phase, which to a certain extent brings the age of our rocks nearer that of the rocks of those distant regions. The geological conditions, characterizing the relations of the Caucasian ultra-basites to the rocks they are contained in, the general data on the tectonics of the country taken into consideration, are conducive to the correlation of the systems of the above-mentioned lines of dislocation, chiefly, with the Hercynian and, apparently, Caledonian diastrophism. So far we have been unable to differentiate them.

It seems to me that there are sound reasons to believe that the tectonic forms which have developed as a result of the Hercynian orogeny, do not only

* Consequently we are dealing here with lines of the Caucasian strike as well as lines with a direction close to uralites.

influence the trend of the Caucasian river valleys and lines of Alpine dislocation [I. V. Popov(5)] but are predetermining them. And if we take the SO : 110° strike to be due to Alpine dislocations, we find the strikes for the Hercynian and Alpine lines to coincide. Emphasis should be placed on the quite regular concomitance of serpentines and members of rocks of the basic and acid magma of various granitoids, quartz diorites, diorites, syenites and syenite-diorites. Along the rivers Belaya, Malaya Laba, Bolshaya Laba, Urup, Zelenchuk and Kuban, etc., these rocks are seen in close association with one another and linked by a common tectonic structure to which they are confined. Careful note should be taken of the fact that the lines I consider as marking the direction of the ultra-basic intrusions as SO : 110°, show strict coincidence with those connecting intrusions of the same type of acid and basic magma. The so-called northern granites of rivers Belaya, Beskes, Indysh, Kuban, Malka, Tyzyl, etc., are immediately adjoining the serpentine massifs, and outcrops of the former and the latter intrusive bodies are confined to the axes of the anticlines or to their limbs. In my opinion it is exactly this concomitance which ought to account for the age discrepancies between ultra-basites, basic and acid rocks. There may be reason to believe that in some cases we are dealing here with a sole intrusive period which produced the entire complex of rocks under description. Hence there is room for the assumption that intrusions of these rocks may be overlapping, and consequently the ultra-basites may sometimes present but products of the utmost differentiation of the common parental magma.

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CRYSTALLOGRAPHY

INTERCHANGE OF BASES IN CRYSTALS OF BETA-ALUMINA

By N. A. TOROPOV and M. M. STUKALOVA

(Communicated by F. J. Loewinson-Lessing, Member of the Academy, 26. V. 1939)

In studying the crystal phase of the binary system barium oxide—alumina we discovered (1) barium aluminate, having a very high alumina content. The composition of this aluminate is expressed satisfactorily enough in the formula $BaO.6Al_2O_3$. The structural and chemical analogy of this aluminate to the varieties of «beta-alumina» described earlier made us immediately advance the hypothesis that this aluminate belongs to a special, unknown barium variety of beta-alumina.

An X-ray analysis afterwards confirmed this supposition. The molecular base content, however, was unusually high in comparison with the other form of beta-alumina. The base was barium oxide in our aluminate.

According to the observations of Ridgway, Klein and O'Leary (2) the content of beta-alumina in white fused corundum, prepared in the works of the Norton Alundum Company, is proportional to its sodium oxide content.

Since the material consists entirely of beta-alumina when the sodium oxide content is 4.76 per cent, the following formula is given to it: $Na_2O \cdot 12Al_2O_3$. An analogous result was obtained for the potassium form of beta-alumina, where the potassium oxide content in the pure varieties equals 6.94 per cent, which corresponds to the formula $K_2O \cdot 12\ Al_2O_3$.

The rest of the X-ray studies of the structure by Bragg, Gottfried and West (3), Beevers and Brohult (4) and Beevers and Ross (5) showed that the correlations between the density and the X-ray data correspond much more satisfactorily to the formulae: $Na_2O \cdot 11Al_2O_3$ or $K_2O \cdot 11Al_2O_3$, which correspond to a sodium oxide content of 5.23 per cent, or a potassium oxide content of 7.75 per cent.

Westgren, Lagerquist and Wallmark (6) described analogous phases in the systems $CaO—Al_2O_3$ and $SrO—Al_2O_3$, expressing the composition of the phases in the form of $3CaO \cdot 16\ Al_2O_3$ and $3SrO \cdot 16Al_2O_3$.

Afterwards Adelsköld (7) identified these compositions with our formulae $BaO \cdot 6Al_2O_3$—$CaO \cdot 6Al_2O_3$ and $SrO \cdot 6Al_2O_3$.

In our joint paper Toropov (1) has expressed the assumption that barium oxide forms a singular solid solution in the space lattice of beta-alumina. This was borne out by the structural proximity of the alkali and alkaline-earth forms of beta-alumina, mentioned above, which are considered a special polymorphic modification of aluminium oxide.

In pursuing further our study of the crystals of barium beta-alumina we discovered another remarkable property in them, which consisted in the capability of these crystals to interchange bases when they are treated with fused salts of alkali and alkaline-earth metals.

Having fused crystals of barium beta-alumina together with potassium carbonate and then having treated them with hydrochloric acid, we observed first of all that they dissolve only very little in this reagent.

Further study of the optic properties of crystals of barium beta-alumina fused with sodium carbonate and treated with hydrochloric acid (1 : 1) showed that their values of double refraction and light refraction had suffered a pronounced change.

Optic Properties of Beta-Alumina Crystals

	Initial barium beta-alumina crystals	The same crystals fused with soda
Optic sign	negative	negative
Character of ellipsoid	uniaxial	uniaxial
N_o	1.702±0.002	1.686±0.002
N_e	1.694±0.002	1.650±0.002
$N_o - N_e$	0.008	0.036

A study of the densities of both materials gave the following results: initial $D_{25°}^{4°} = 3.63 \pm 0.01$, after treatment $D_{25°}^{4°} = 3.33 \pm 0.01$.

It was natural to suppose that the chemical composition of these crystals had also changed. An analysis of the solution obtained by treating a fused mixture of soda and barium beta-alumina with hydrochloric acid showed the following barium oxide content:

	Experiment 1	Experiment 2	Experiment 3
BaO in solution	17.72 p. c.	16.51 p. c.	15.90 per cent.

The greatest difficulty was met with in analyzing the insoluble residue, since in this case the reagents to be used for determining alkalis in crystals of beta-alumina which are decomposable just as corundum only by means of very strong reagents, had to be free from alkali.

At first the alkali determination was performed by preliminarily fusing beta-alumina with boric acid and $CaCO_3$ (5 : 1), free from alkali, and then removing boric anhydride in the form of boro-methyl ether. After this it was possible to use Lawrence Smith's method slightly modified. After being carefully pulverized the material is heated strongly with a mixture of ammonium chloride and calcium carbonate, and then the alkalis are determined in the usual manner in the form of chlorides.

We analyzed two samples, fused with sodium carbonate and treated with hydrochloric acid (1 : 1). The result of this analysis was entirely unexpected, since the figures obtained for the sodium oxide content in the crystals were considerably higher than not only Ridgway, Klein ad O'Leary's limit practical figures, but also the theoretical quantity 5.23 per cent which is represented by the formula $Na_2O \cdot 11Al_2O_3$.

In our sample we found sodium oxide 6.70 per cent and barium oxide 0.30 per cent in the first and sodium oxide 6.52 per cent and barium oxide 0.70 per cent in the second.

We came to even greater discrepancy with our predecessor in studying crystals of barium beta-alumina fused with potassium carbonate and then

treated with hydrochloric acid (1 : 1). Having fused finely powdered crystals of barium beta-alumina twice with potash in a quantity six times as great as the weighed portion of alumina and having treated it with hydrochloric acid (1 : 1) we obtained a substitution product, an analysis of which gave the following results: potassium oxide 10.16 per cent; barium oxide 4.18 per cent. A detailed microscopic study of this product showed that it was fully homogeneous and that the values of the optic constants were intermediate between those for $BaO \cdot 6Al_2O_3$ and those for $K_2O \cdot 12Al_2O_3$. Namely we obtained the following values for the indices of light refraction of these crystals: $N_0 = 1.696 \pm 0.003$, $N_e = 1.660 \pm 0.003$, $N_0 - N_e = 0.036$. The density of these crystals determined pycnometrically was as follows: $D^{4°}_{25°} = 3.393$ and $D^{4°}_{25°} = 3.403$, or on the average $D^{4°}_{25°} = 3.398 \pm 0.005$, which is also a value intermerdiate between the densities of $BaO \cdot 6Al_2O_3$ and $K_2O \cdot 12Al_2O_3$.

Calculating the chemical composition of the homogeneous product obtained, we got the following value for the ratio between the bases K_2O and BaO, on the one hand, and Al_2O_3, on the other—0.1348 : 0.8388, which corresponds to the formula $(K_2,Ba)O \cdot 6.22Al_2O_3$ or 0.964 $(K_2,Ba)O \cdot 6Al_2O_3$.

The next experiment consisted in fusing a weighed portion of barium beta-alumina three times with potash and then treating it with hydrochloric acid (1 : 1). The product obtained had the following chemical composition K_2O—13.75 per cent, BaO—0.22 per cent.

Appropriate recalculations gave the following ratios between the bases K_2O and BaO and the alumina in the product: $(K_2, Ba)O \cdot 5.72\ Al_2O_3$ or 1.048 $(K_2, Ba)O \cdot 6Al_2O_3$.

The third experiment of this series consisted in replacing the barium oxide in beta-alumina with rubidium oxide. The mixture was fused once and rubidium chloride was taken in three times the quantity of barium beta-alumina, since the displacement reaction with chlorides goes on analogously to the same reactions with carbonates. As a result of the treatment described above we obtained a substitution product, an analysis of which gave the following data: BaO—11.63 per cent; Rb_2O—6.33 per cent. Recalculation of the ratio between the bases and alumina gave the following result in this case: $(Ba, Rb_2)O \cdot 6.37\ Al_2O_3$ or 0.800 $(Ba, Rb_2)O \cdot 6Al_2O_3$.

In all these cases we found a considerably higher content of alkali atoms in the lattice of beta-alumina than was given by other authors.

If we compare these values for the composition of various beta-aluminas, and take account of their common origin from barium beta-alumina, in which the ratio of the bases to alumina equals six, we naturally come to the conclusion that there exist not only alkaline-earth forms of beta-alumina, whose composition can be expressed in the following manner: $MeO \cdot 6Al_2O_3$, where Me represents Ca, Ba, Sr, but that it is possible to produce crystals of the alkali forms of beta-alumina having the composition $Me_2O \cdot 6Al_2O_3$, where Me represents K, Na or Rb.

At the present time we are studying interchange reactions between barium beta-alumina and lead carbonate.

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GENETICS

TRANSFORMATION OF THE NORMAL GENOTYPE IN WILD *DROSOPHILA MELANOGASTER* POPULATIONS

By J. M. OLENOV and I. S. KHARMAC

(Communicated by N. I. Vavilov, Member of the Academy, 8. VI. 1939)

In our paper dealing with the analysis of the genic composition of a *Drosophila melanogaster* population from a fruit canning factory at Uman we have shown that the alteration of the normal phenotype which was frequently observed in this population in summer 1937 (abnormalities in the veining in the wing involving the crossvein posterior) is in different strains due to different genetic factors: when intercrossed these strains in most of the combinations produce a normal progeny([1]). Having considered this fact in the light of other data we have shown that this case should be understood as an instance of the effect of natural selection which destroys the noxious influence of the mutant gene and includes this gene into a normal genotype. The principal gene responsible for the appearance of a certain character is of wide occurrence in the population, but it is expressed only in the presence of activating modifiers. The abundance of modifiers capable of activating the expression of the principal gene proves that the process of its inclusion into the normal genotype is far from having come to a close. The results of analysis of the Uman population of 1937 together with the existing literary data* made us suggest that the process of inclusion of mutant genes into a normal genotype is of common occurrence in wild populations of *Drosophila melanogaster*. Our aim was to verify the exactness of this assumption. With this purpose in view we studied all the visible mutations belonging to the II chromosome which came to our observation in the Uman population in summer and autumn 1938, as well as all the visible mutations in the Bobrov population (Voronezh region) and in that of Simferopol (Crimea)** analyzed at the same time. Special attention was paid to such characters which, while appearing in some strains as the sole recorded change, occur at the same time as a peculiarity accompanying the principal manifestation of other genes, because, as previously mentioned, many visible mutations belong to the number of activators of the gene, included as an effect of selection into the normal genotype.

From the results of the study of the apparent mutations included into the II chromosome in the Uman summer and autumn population of 1938 it may be seen that apart from the changes in the crossvein posterior further five alterations presenting an analogous picture of inheritance were brought into evidence. Four of these—not unfolded or

* We may cite, for instance, the work of Panina ([2]) who has observed evidence of the polyfactorial nature of the caracter «additional bristles». The character mentioned was discovered by Dubinin, Romashev and others ([3]) in several populations in some of which it is of frequent occurrence.

** The results of the analysis of the genic composition of the three populations undertaken in summer 1938 are discussed elsewhere ([4]).

not definitively unfolded wings, divergent wings, indentations in the inner edge of the wing, dachsoid legs—are incompletely manifested like the abnormality in crossvein posterior. The same four alterations have been frequently noted as a part of the pleiotropic effect of other visible mutations. The strains in which all these five alterations have been observed together with changes in the crossvein posterior are found in 50 to 60 per cent of all chromosomes containing visible mutations. We undertook the study of visible mutations observed in the Uman population during summer 1937 and found that in this case also these changes amounted to about 40 per cent of all visible mutations. These values are probably somewhat underrated, since it is quite possible that some of the single or rare changes belong into this class, too.

The Uman population is no exception. In the Simferopol population more than a third (9 out of 5) of all visible mutations belong into the same category. In the Bobrov population the alterations produced by modifiers of the genes which later on are included as an effect of selection in the normal genotype constitute the great majority (23 out of 28) of all visible mutations found in this population.

We may consequently assert that by natural selection mutant genes are simultaneously included into the normal genotype of wild *Dr. melanogaster* populations, that the transformation of the normal genotype is a mass process continuous in its progress. The transformation of the normal genotype occurs no doubt not only at the expense of visible mutations—of great importance are therein the transgenations which produce no phenotypical changes which might be recorded with the help of the sampling method usually employed. Such an idea of the normal genotype seems to be a certain progress compared with the generally accepted view according to which the normal genotype is taken to represent a relatively stable system. Our idea of the normal genotype is in good agreement with the data scattered in literature relative to the slight physiological differences existing between populations in a species in which no clearly delimited races can be distinguished. The origination of new varieties and races—the starting point of the species producing progress—appears to us not as movement beginning in every case from some stationary point, but as a necessary result which is now and then caused by the action of natural selection which continuously transforms the normal genotype.

One of the effects due to transformation of the normal genotype in wild *Dr. melanogaster* populations is the peculiarity of the genetic composition of these populations in the visible mutations. Besides the usual monofactorial changes we find in the population numerous strains which are phenotypically similar to one another or nearly so, but contain different modifiers of genes included in the normal genotype. The process of transformation of the normal genotype produced instability of the phenotype, and the consequence is that numerous mutations which phenotypically do not affect the strains with a maximally balanced genotype come here to manifest themselves phenotypically.

Knowledge of the viability of strains showing activation of the genes which enter the normal genotype, is of paramount interest since it may help in obtaining data on the quality of the material that had served for natural selection. The data at our disposal were obtained from the Uman population; they refer to the relative viability estimated according to the deviation from the expected 2 *Cy*: 1 non-*Cy* rate in F_3 in the analysis of the II chromosome of wild specimen (the number *Cy* was accepted as equal to 2*).

* The concentration of hereditary changes in viability in wild populations was studied in our laboratory by G. D. Muretov. The results of these investigations are discussed in a separate publication ([5]).

The strains in which different phenotypical changes are expressed, i. e. in which activation of different genes had taken place, differ in their viability, too. The highest viability comes to view in strains characterized by aberrations in the veining in wings involving the crossvein posterior. In these strains the viability mean (78.8±0.5 p. c. for the Uman and 85.9±0.6 for the Simferopol material) differs but slightly, if at all, from the viability of wild strains free of apparent changes (81.2±0.3 p. c. for Uman and 85.7± ±0.1 p. c. for Simferopol). By applying the method used by Dobrzhansky and Queal([6]) evidence may be obtained that the deviation from the expected ratio 2 *Cy* : 1 non-*Cy* in strains free of visible mutations and in strains in which the crossvein posterior is involved are due not to an insufficient adaptation to laboratory conditions of the flies, in which both II chromosomes belong to wild populations, but to homozygotization of semilethals occurring in wild conditions: in intercrossings of non-identical wild strains of the Uman population (*Cy*×*Cy*) the viability of the non-*Cy* specimen is found to amount to 101.0±0.5 p. c.

Out of other changes produced by activation of genes which come to be included into the normal genotype, a viability average over 50 p. c. was found for «divergent wings» and «indentations in the wings». The viability rate in strains in which in homozygous specimens the wings are not fully unfolded has in our investigations never been above 50 p. c., amounting in most cases to 20 or 30 p. c. The «dachsoid legs» strains differ sharply from one another (here are taken into consideration the results of the investigation of 1937 when this alteration was more frequent in the population), and it should be stated that in strains in which the character in question was but slightly manifested and feebly expressed we find a high viability rate (up to 60 p.c.), whereas in strains in which the character is fully manifest and strongly expressed the viability rate is considerably diminished (not above 5 p. c.). And lastly a most strikingly low viability is proper to the strains «raised wings». In all 7 strains found in Uman populations the viability rate of the homozygotic non-*Cy* specimen was below 1 p. c.

Not all the genes included by selection into the normal genotype diminish the viability rate after having been activated, as may be seen from the numeric data relating to the strains in which crossvein posterior is involved. The data now at our disposal give no cue as to which of the two possible explanations of this fact is the more plausible (whether it is the original peculiarity of the principal gene, or the more advanced stage of the process «redressing» the genes). The data obtained for the «dachsoid» strains indicate that, apart from the possibility of the chromosomes being in some cases overcharged with a foreign semilethal, the activators of the genes entering into the normal genotype differ in these strains from one another with regard to their effect on the strain's viability. Anyhow, there is no doubt that some of the genes which are involved in the transformation process of the normal genotype (the principal genes—«dachsoid» and especially «raised wings») in some genotypical combinations occurring in the population act as strong semilethals. This conclusion is but seemingly a paradoxical one since, contrary to such changes as the crossvein posterior, «indentations in the wings» and «divergent wings», the mutations activating the principal genes «dachsoid» and «raised wings» are of rare occurrence, and selection may easily outweigh the noxious effect of the mutational process. (In the course of our investigation of the mutational process in the Uman strains no mutations of this sort ever came to our observation whereas activation of other principal genes occurred repeatedly). It may also be noted that selection effecting the inclusion of a part of the mutant genes in the normal genotype acts in the same direction on several other visible mutations bringing their viability nearer to the norm([4]).

Data on the viability of the «raised wings» strains and of some of the «dachsoid» strains agree well with the view on the mechanism of the action of genes in ontogenesis recently advanced by Schmalhausen (7). If the mutant gene, included by selection into the normal genotype produces a still possible change in the rate of the one of some two reactions, the course of which must be partly synchronous as a necessary condition for a normal viability of the individual at a given developmental stage—in that case every transgenation which definitely disturbs the correlation between these two reactions will cause a sharply pronounced effect, although in some other genotype its effect may be practically null. This interpretation is, of course, equally applicable to the phenotypic peculiarities of the strains in which are activated the genes that enter into the normal genotype.

In conclusion we must briefly discuss the question as to the causes of the transformation of the normal genotype in wild populations. To begin with, we must insist on the fact that transformation of the normal genotypes is by no means an exclusive property of highly mutable populations. This is evident from the data obtained for the Simferopol population which is not highly mutable (4). It is, however, quite possible that the transformation process has a more rapid course in populations characterized by a high general frequency of mutations, especially subsequent to a change in conditions of existence and a corresponding change in the direction of selection. Another consequence of a high mutability, directly opposite in its import—namely a more frequent activation of genes entering into the normal genotype—must likewise be considered. By the relation between those two factors the rôle of the mutational process is determined. Moreover, as we already have mentioned on another occasion, an inclusion of mutant genes into the normal genotype as an effect of selection is most probable for genes attaining high concentration. And since mutating genes possess on the average rather frequently greater chances of spreading in a population, the qualitative peculiarity of the mutational process must impress in a certain way the material acted upon by selection.

Summing up, we may say that transformation of the normal genotype is not a consequence of high mutability characteristic of certain populations, although a higher frequency of origination of mutations may probably accelerate or in some cases retard the process. The causes of this continuous transformation must be investigated in detail. But even now we have reason to assert that the fluctuation, variety, complexity and contradictory relations of the species to its environment, increased by repeated migrations and partial isolation, play here a decisive rôle. This may be concluded from a comparison of the results of a study of the genotype of wild populations with the data obtained on laboratory strains, a generalization of which has led to the conception of a normal genotype as of a comparatively stable system.

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GENETICS

FACTORS RESPONSIBLE FOR THE GENIC COMPOSITION OF WILD *DROSOPHILA MELANOGASTER* POPULATIONS

By J. M. OLENOV, I. S. KHARMAC, K. F. GALKOVSKAYA, G. D. MURETOV

(Communicated by N. I. Vavilov, Member of the Academy, 8. VI. 1939)

The value of genetic methods in the study of the origin of species stands out most distinctly in the researches dealing with the genetics of wild populations. By examining the genic composition of populations, by tracing the changes that occur in them, by making an analysis of the causes responsible for the trend and rate of these changes we inquire into the initial stages of the process of species formation. The next stages—origination of new races and varieties, and, finally, of subspecies and species—have for their basis the divergent development of populations.

In a previous publication [1] we described the genic composition of *Drosophila melanogaster* populations from the fruit preserve factory at Uman (Kiev region, Ukraina), and the alterations observed in it during summer and autumn 1937. In the present paper we aimed to compare the genic composition of populations at the time of its sharp numerical decrease (winter, spring and early summer when no ripe fruits are available) with the changes observable in the same population when at its best. Moreover, it was necessary to find out to what extent the population studied reflected the relations typical for *Dr. melanogaster* populations, and to check some of the former conclusions of theoretical importance.

The concentration of lethal and visible mutations has been studied on three populations from fruit factories: at Uman (the specimens were collected at the same factory as in 1937), at Bobrov (Voronezh district) and at Simferopol (Crimea).

Analyses of the II chromosomes were made by means of the $\frac{Cy\ sp}{L^2}$ method.

Two samples—I and II—were collected at Uman on 14/VII and 10/IX respectively, one sample was taken at Simferopol on 15/VII, and one at Bobrov on 29/VIII. Further study was made of the mutation frequency in the II chromosome in the same populations, for which purpose several $\frac{Cy}{II}\ \frac{sp}{n}$ males were secured respectively from 20 strains of the Uman population (sample I), from 17 strains of the Bobrov and 10 strains of the Simferopol population. The strains employed in this investigation, as established by previous analysis, contained neither lethal nor visible mutations. With reference to

every $\frac{Cy}{II}\ \frac{sp}{n}$ a study had been made of several chromosomes and in this way it was easy to detect all the cases when a lethal mutation had originated in one of the preceding generations. Moreover, with the purpose of finding out the cases when lethals appeared in clusters, the identification of lethals that had appeared in the progeny of one male was undertaken.

Table 1

Mutational Process in the II Chromosomes of Wild Population (1938)

Populations	Number of chromosomes studied	Number of lethal mutations found	Number of independent originations	Rate of lethals to total number of chromosomes studied
1. Uman 1938	340	20	16	5.9 ± 1.2
2. Bobrov 1938	435	20	18	4.6 ± 1.0
3. Simferopol 1938	400	2	2	0.5 ± 0.3

Diff. $_{1-2}$ $= 5.4 \pm 1.2\%$

Diff. $_{2-3}$ $= 4.1 \pm 1.0\%$

The mutation frequency in the II chromosomes of the Uman population in summer 1938 (Table 1) was found to be as high as that of the year 1937 or even higher (the difference is not authentic: in the II chromosome belonging to the sample secured in summer 1937 the percentage of gametes containing lethal mutations belonging to one generation was of 4.2 ± 1.0). Such a high frequency of mutation, unusual for laboratory strains, is, however, no specific feature of the Uman population. An analogous result was obtained from the analysis of the mutational processes in the II chromosomes of the Bobrov population. On the other hand, a small per cent of mutations found in the II chromosome of the Simferopol population simultaneously studied shows that the high mutation frequency in the flies of the Uman and Bobrov populations is not due to any special breeding conditions (the experiments were carried out at 25° C and the usual yeast medium served for nutrition). The difference in the rate of mutations in the Uman and the Bobrov strains as compared with the Simferopol strains is quite significant, and the results obtained make us recognise that mutation frequency in wild populations may highly differ being in some populations 10 times as high as in others. It should also be noted that a comparison of the results of our investigations with literary data available ([2]) gives so far no ground to suppose that the difference in the mutability of geographically distant *Dr. melanogaster* populations can be explained by macroclimatic influences*.

By comparing the concentration of lethal mutations in the Uman population on 14/VII 1938 (sample I) and on 10/IX 1938 (sample II) we find that in this interval the mutational process has produced a significant increase in the percentage of lethals contained in a population (Table 1). Thus, we now are entitled to speak not only of a trend to an increase of the total

* The high mutability characteristic of certain wild *Drosophila melanogaster* populations (as formerly indicated this refers not to autosomal genes only, but also to genes localized in the X-chromosome) has its analogy in the recently published data on the variability of the wild growing wheat species([3]). With better knowledge of the genetics of wild populations such instances will presumably grow more numerous.

concentration of mutations at the period when a population has reached its numerical maximum—that is at the period when the population is in its prime (this tendency has already been noted in 1937 when the Uman population was studied)—but as well of an actually occurring increase of the concentration (this fact is a further proof of the high mutability of the Uman population). But although towards the close of the period studied the total rate of lethals contained in the population was very high, yet the selection under these conditions could not compensate for the progressive overloading with lethals produced by the mutational process. An identification of 27 of the lethals found in the population of 14/VII did not show a single case of identity. Consequently, it may be concluded that the concentration of each lethal gene or at least of the majority of lethal genes, is a very low one, amounting to less than 1 p. c. In view of such a low concentration of the lethal genes and the high frequency of the lethals the population is very far from attaining a state of equilibrium between the eliminating effect of selection and the mutational process. And this is equally true of the highly mutable Bobrov population. Identification of all the 28 lethals found in this population has shown that here also the concentration of each lethal mutation is not above 1 p. c. Finally, even in the Simferopol population which exhibits no high mutability and in which some lethal genes have a concentration as high as 2 p. c. (on the whole 28 lethals were identified), the frequency of lethal mutations originating in the germ cells of each generation—0.5 p. c. for the II chromosome—greatly exceeds the effect of selection and owing to this a gradual increase in concentration of lethal mutations must take place.

However, the rôle of the mutational process, on the one hand, and that of selection, on the other, appears in quite a different light when we compare the concentration of mutations found in the Uman population in autumn 1937 and in summer 1938. In the winter-spring period the concentration of lethals has remained at the same level. This fact cannot be explained by a slowing down of the mutational process, since at the same time the concentration of visible mutations was sharply increased (Table 2). The increase

Table 2

Concentration of Mutant Genes in Wild Populations

Populations	Number of chromosomes studied	Number of lethals	In percent	Total number of visible mutations found	In percent	Among them monofactorial visible changes	In percent
1. Uman 11—25/IX 1937	1376	311	22.6±1.1	78	5.7±0.6	45	3.3±0.5
2. Uman 14/VII 1938	589	127	21.6±1.7	93	15.8±1.4	58	8.1±1.0
3. Uman 10/IX 1938	735	219	29.8±1.7	136	18.4±1.4	58	7.9±1.0
4. Bobrov 29/VIII 1938	215	28	13.0±2.3	28	13.0±2.3	5	2.3±1.0
5. Simferopol 19/VII 1938	426	88	20.6±2.2	25	5.9±1.1	16	3.7±0.9

Diff. $_{2-3}$ for lethals=8.2±2.4

Diff. $_{1-2}$ for monofactorial visible changes=4.8±1.2

in rate of visible mutations is fully significant even in the case when simple monofactorial changes alone are considered, leaving aside the alterations produced by activation of the genes included by selection into the normal genotype ([4]). The increase in concentration in visible mutations and the absence of a parallel change in the concentration of lethal genes may easily be explained if we take into consideration that in the winter-spring period the population is considerably decreased and segregates into separate micropopulations. The consequence of these seasonal changes is a strong increase in inbreeding and accordingly an increase in the efficiency of natural selection. A certain degree of inbreeding and a certain initial (autumn) concentration of lethals and of visible changes being present, the eliminating action of selection will be on the par with the mutational process as regards the lethal mutations,—yet an increase in the concentration of visible mutations may possibly occur. It should be noted that at various degrees of inbreeding due to a greater or lesser decrease of the population and according to the degree at which the autumn population previous to its decrease in number differs from the state of equilibrium—between the eliminating action of selection and the mutational process—with regard to the visible and the lethal mutations, the result of the seasonal decrease of the population will prove to differ. Thus, e. g., the decrease in the rate of lethals and at the same time of visible mutations, as reported by Dubinin, Romashev and others ([5]) in the Guelendjick population in 1935 as compared with 1934, is obviously due to the fact that, considering the mutability proper to this population (the possibility of seasonal variations in the frequency of origination of mutations and the intensity of germinal selection must not be ignored either) and the original—autumnal—concentration of mutant genes, the decrease in the population was so striking that selection was capable to markedly purify the population not only from lethal but also visible mutations. The opposite case is theoretically equally possible: in a highly unstable population or in a population which contains at the given moment few mutant genes, or remains rather numerous and not segregated into separate micropopulations (a simultaneous action of all these factors is of course also possible) during the winter-spring period an increase in the concentration of both visible and lethal mutations will take place. Such a case is, however, not characteristic for most *Dr. melanogaster* populations, and the concentration of mutant genes usually takes the form of a more or less sharply expressed increase of this concentration, owing to the mutational process at the time when the population is in its summer and autumn prime, which in the winter and spring period gives place to a reverse situation. Both tendencies may act in different cases with a different force. Therefore a population which has passed through a complete yearly developmental cycle may in the course of it display considerable changes in the one or the other direction, and various populations may sharply differ from each other according to the degree of their contamination with mutant genes [comp. the data of Dubinin, Romashev and others ([5],[6],[7]) referring to the genic composition of geographically distant *Dr. melanogaster* populations and the changes occurring in the course of the year in some of the populations].

The total concentration of lethal and visible mutations in wild populations, as has just been demonstrated, is dependent upon the interconnexion between selection and the mutational process. The genetico-automatic processes, that is the changes in the concentration of genes caused by incidental survival or death of heterozygous individuals in the period when the populations grow less numerous [Dubinin, Romashev and others ([5],[6],[7]), comp. Elton ([8])] obviously play along with the mutational processes and selection a considerable rôle in the determining of the concentration of each

separate gene; they are to a considerable degree responsible for the concentration which is at the moment characteristic of the mutant gene*.

As, however, with the decrease of the population the efficiency of selection is heightened, the concentration of each of the lethal genes in the average proves to be lower than that of the genes responsible for the «visible» changes.

In conclusion we particularly insist on the fact that the rôle of selection is not restricted to its influence as a factor counteracting the effect of the mutational process and eliminating noxious hereditary changes. Selection introduces some mutant genes into the normal genotype ([4]) and at the same time it «redresses» some of the mutations in which phenotypical expression is retained. Among forms homozygous for some visible mutation that specimen has the greater chances of surviving and of producing progeny, in the genotype of which the noxious effect of the appropriate gene is toned down. This process of increase in viability of visible mutations must be the cause of distinctly apparent differences in the average viability of strains containing shortly originated mutations as compared with strains in which mutant genes had been retained by the population over a relatively large number of generations. The eliminating action of selection increases this difference, since mutations by which viability is not markedly abated will more frequently be retained in the population. For this reason in highly mutable populations which contain numerous recently originated mutations the average viability of homozygous mutations must be lower than in populations in which the mutational process has a slow course. Indeed, the average viability of specimens homozygous for visible mutations** estimated in the analysis of F_3 by the deviation from the expected relation 2 *Cy*: 1 non-*Cy* (the value *Cy* was accepted as 2) is found to be much lower in Uman ($41.3 \pm \pm 0.5$ p. c.) than in Simferopol (66.5 ± 0.4 p. c.) whereas on the whole, with reference to all strains containing neither lethal nor visible mutations, this difference, although existing, stands out less sharply (81.2 ± 0.3 p. c. for Uman and 85.7 ± 0.1 p. c. for Simferopol).

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* Dubinin and co-workers([5]) point to the fact that the genetico-automatic processes play a decisive part in indifferent mutations only. It is, however, permissible to question the very existence of indifferent mutations. In particular, the reasoning which claims to prove their existence in a population (number of homozygotes coincides with the expected number, according to Hardy's rule) is not conclusive, since one generation suffices for the equilibrium to set in between the number of homo- and heterozygotes, while the intensity of selection may vary, expecially in connexion with the seasonal variations of the surrounding medium.

Neither are conclusive the attempts—for the same reason—to prove that concentrations of chromosomal changes in wild populations of various *Drosophila* species are not subject to the influence of selection and that fluctuations in these concentrations are due to incidental causes [Dubinin and his co-workers([9]), Koller ([10])].

** Simple monofactorial changes only were considered, since for the viability of numerous changes due to activation of genes introduced by selection into the normal genotype([4]) other much more complex causes are responsible.

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GENETICS

PHYSIOLOGICAL MUTATIONS AND DYNAMICS OF THE GENIC COMPOSITION OF *DROSOPHILA MELANOGASTER* POPULATIONS

By G. D. MURETOV

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As already stated in Muller's[4] first article dealing with the origination of hereditary changes as effected by X-rays, besides lethals and visible mutations, hereditary changes make their appearance, owing to which the viability in homozygous forms is abated to a certain degree without occasioning any noticeable alterations in the phenotype. Their presence may be recognized only by some deviation in the expected splitting in certain systems of crossings. Exact data characterizing the frequency of their appearance as an X-ray effect in the sex chromosome in *Drosophila melanogaster* were given in 1934 by Timofeeff-Ressovsky and by Smirnov ([7], [10]), in 1938—by Kerkis[2]. The value of this «small» «physiological» mutation for the solution of problems of evolution has been repeatedly stressed, especially by Baur[1] and Timofeeff-Ressovsky[9]. In view of the above, we thought it of interest to look for a solution of the question as to the occurrence of mutations of this sort in wild *Drosophila* populations, inasmuch as corresponding data are totally lacking in literature *.

In autumn 1938 we made a detailed analysis of 426 II chromosomes from wild *Drosophila melanogaster* populations of Simferopol (Crimea). The method employed was the $\frac{Cy\ sp}{L_2}$ method. In F_3 a splitting at a rate of 2 : 1 is expected (2 heterozygotes for *Cy* and the wild chromosome to 1 represented by a group of specimens homozygous for the «wild» chromosome), given that the homozygote has a normal (100 p. c.) viability; and on the other hand every possible ratio beginning with these relations and down to 2 : 0 may appear if lethal or semilethal mutations are contained in the chromosome.

With the view of creating the greatest possible uniformity in developmental conditions and to obtain large numbers in F_3, we secured among F_2 six *Cy* ♀ ♀ and crossed them with *Cy* ♂ ♂ belonging to the same strain. The flies were placed in test tubes so that each tube contained 2 ♀ ♀ and 2 ♂ ♂. After a period of four days the parental flies were shaken out. Two counts of the cultures were made on the second day after the emerging of the flies and on the fifth day when the process had practically come to a close. Table 1 repre-

* It is only when the present work was nearing its close, that a paper by Dobzhansky and Queal dealing with an analogous subject and carried out on *Dr. pseudoobscura* populations appeared in print.

The conclusions that may be drawn from a comparison of the results of our and of Dobzhansky's investigations cannot be discussed here for lack of space.

Table 1

Viability p. c.	0	2	5	15	25	35	45	55	65	75	85	95	105	115	125	135	Total
Number of cultures	90		4	12	7	6	9	7	8	18	45	70	87	33	19	2	417
Rated against the general number of chromosomes	21.60		0.96	2.88	1.68	1.44	2.16	1.68	1.92	4.32	10.80	16.80	20.85	7.92	4.55	0.48	100

sents the distribution of cultures according to the relative viability of their homozygotes as estimated by the observed grade of deviation from the 2 : 1 ratio (taking the number of *Cy* flies present in each culture as 2). In the average counts of 420 flies were made in each culture. Nine strains in each of which F_3 contained less than 100 *Cy* flies are not included in the Table 1*.

The deviation in the numbers of non-*Cy* flies emerged was estimated according to its significance**. In the figure representing the respective classes as rated in per cent against the number of chromosomes analyzed the dubious deviations are shaded.

We see that 3 mean errors eliminate all save one positive deviation and part of the negative deviations to 55—65 p. c. relative viability class.

Distribution within the normal group, that is the group of cultures in which the deviations lie within $\pm 3\ m$, is strikingly asymmetric. This means that in «wild» chromosomes besides semilethals by which viability it considerably abated mutations producing but a slight decrease in viability are likewise present.

The asymmetry stands out most sharply when all the «normal» cultures are classed according to their deviations from an expected magnitude as expressed in errors.

The table indicates that plus-deviations do not as a rule overstep the limits of two mean errors, and one case only of a plus $3m$ aberration has been noted which, given the accidentality of such deviations, coincides with the probability of its occurrence.

On the other hand, minus-deviations found in prevalence in 70 culture—which makes 16.7 p. c. of all the strains — cannot be accounted for by haphazard. In our opinion there is full reason to admit that this prevalence is due to a considerable concentration of small mutations and that the 16.7 p. c. is but the minimum rate characterizing their number.

The authenticity of the curve's asymmetry is unquestionable from another viewpoint. Thus, in the «normal» cultures 114282 flies were counted in all; it follows that the expected number of non-*Cy* flies — $33.33 \pm 0.13\%$ (38094), but the number of flies that had actually emerged is 36914 which makes $32.30 \pm 0.14\%$

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* Considering that in heterozygous $\frac{Cy\ sp}{+}$ ♀ crossingover still occurs with a frequency up to 1 p. c., we put all strains in which non-*Cy* flies were found to be present at a rate 1 p. c. into the class of lethals.

** The expected numbers were calculated according to the formula $q = i\,\frac{n}{k}$ where i is one of the ideal numbers (2 or 1), n—the number of flies in the culture, k—the total of ideal numbers. The average error was calculated according to the formula $m = \pm\sqrt{\frac{q\,(n-q)}{n}}$.

Table 2

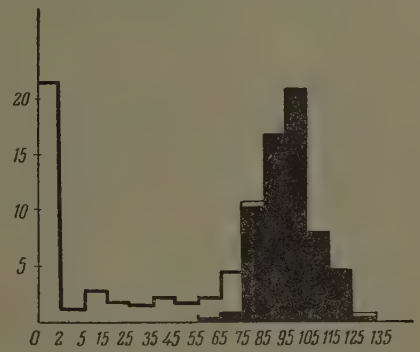
	Lethals	Semilethals	Normal groups	Strains showing an significant increase in viability
Number of cultures	90	66	260	1
As rated in % against the total number of chromosomes	21.60±2.01	15.79±1.78	62.57±2.37	0.24±0.23

of the total number of flies. The difference amounting to 1.03 is 5.4 times greater than the error.

Table 3

Deviations as expressed in errors	−3	−2	−1	+1	+2	+3	Total
Number of cultures	25	60	74	70	24	1	260
Prevalence of minus-deviations	24	42	4	—	—	—	70

The above is a proof of the presence in wild *Drosophila melanogaster* populations not only of semilethals affecting more or less strongly the viability, but also of physiological mutations which abate it but feebly. On the other hand, on a rough verification of the strains characterized as possessing a heightened viability no confirmation of this peculiarity was obtained.



It may be said on the whole that at least 50 p. c. of II chromosomes are bearers of some or other genetical change of viability (lethal mutation, strong semilethal, physiological mutation).

At the same time the relative character of our data should be held in view; a mutation that decreases the viability under the given conditions of analysis will not necessarily produce a similar effect under natural conditions. While pointing out the relative character of the term «viability abating mutation» we still insist upon the fitness of the method employed, since it reflects the actual heterogeneity of the population's composition. Diploidy of the chromosomes owing to which an immense number of hereditary changes are retained in a heterozygous state is the main factor responsible for this heterogeneous condition.

The trend assumed by natural selection which varies according to season and conditions of development, contributes to the maintainance of this heterogeneous state. Moreover, the variety of microconditions and the differences connected with it in the manifestation of separate large and «small» mutations attaining the homozygous state are likewise active in the same direction. While in the case of lethal mutations their homozygotization leads but to their elimination, for the semilethal, provided it is able to multiply by means of the homozygote, homozygotization plays an important part in the transformation process of its manifestation.

Selection, under conditions of extreme heterogeneity, will always favour the multiplication of such individuals, the viability of which is increased owing to the presence of a favourable genotypical combination.

The process of increase of viability in separate physiological mutation is apparently of great importance for mutations with a viability close to the normal, their being the highest concentration in a population.

It follows that the inclusion into the normal genotype of a series of hereditary changes which do not noticeably affect the phenotype continuously takes place*. This process leads up to an alteration of the genetical basis of character realization.

Under concrete conditions of existence of a population the species'general power for modification is realized only in part. As the manifestation of various mutations included into the normal genotype is correlated by selection in accordance with the conditions of life of the given population and a part of the reactive power proper to the initial system which does not come to realization under the given conditions is destroyed, an indirect fixation of the modification will take place. Indeed, the manifestation of mutations included into the genotype will put out of harmony the ontogenetic process realized under conditions not typical for the given population in so far as their action under these conditions has not been correlated by selection. It should be noted that fixation of the modification is always simultaneous with the extension of the adaptive possibility of the species which coincides in its direction with the action of selection. The process of an indirect fixation of modification ([3]) which according to Schmalhausen ([11]) is due to selection of genocopies may take place on the basis of a selection for viability. Acting upon certain fundamental biological characteristics (viability, fertility, duration of development) selection undoubtedly brings with it correlative changes in the norms of reaction proper to other morpho-physiological characters.

Selection for viability is a species differentiating factor. The nature of differentiation of phenotypes in any two populations is dependent upon the peculiarities of the historically formed initial reactive system([11]). The grade and specificity of their genetic differences are determined in the first place by the various course assumed by the mutational process in these populations.

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* That such a process may equally occur relative to visible mutations may be concluded from a wide occurrence in *Drosophila* populations of a number of feebly penetrating mutations that involve various morphological peculiarities. Thus for instance the variance of crossvein posterior—of frequent occurrence in the Uman population,—is due to the presence in the population's genotype of a widely distributed principal gene, the noxious effect of which is eliminated by natural selection. Deprived of its independent manifestation this gene is actually already included in the population's normal genotype and produces changes in the phenotype only when appropriate modificators are present. The variation of the veining of the wing involving crossvein posterior is but one instance of this sort of characters ([5], [8]).

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GENETICS

DEPENDENCE BETWEEN THE QUANTITY OF THE $\overset{+}{cn}$-SUBSTANCE AND THE STRENGTH OF ITS ACTION IN *DROSOPHILA MELANOGASTER*

By M. E. NEUHAUS

(Communicated by I. I. Schmalhausen, Member of the Academy, 9. VI. 1939)

Mutant allelomorphs of the normal genes most often differ both from one another and from their normal allelomorphs in the strength of their action, i. e. , there exists merely a quantitative difference between the products of the various allelomorphs, and not a qualitative one. In some cases it proved possible to accumulate several mutant allelomorphs in a single organism ([1], [2]); in such cases a reversion to the normal character takes place. Unfortunately the ordinary genetic technique does not allow it to accumulate many mutant allelomorphs in one and the same organism; it remains therefore unknown what would be the effect of quantitative excess of gene products.

The fact that by introducing hormone-like substances of the normal allelomorphs $\overset{+}{v}$ and $\overset{+}{cn}$ to the larvae of the genotype *vermilion* or *cinnabar* deficient for these substances it is possible to produce an effect similar to that obtained in flies showing a normal genotype, permits of a more direct study of the dependence between the strength of action and the quantity of genic products.

Beadle ([3]) has proved that Malpighi vessels are the source of the $\overset{+}{v}$ and $\overset{+}{cn}$ substances. By inplanting to larvae of the genotype *v* or *cn* from 1 to 4 Malpighi tubes of normal larvae Beadle has shown the effect to grow with the number of tubes grafted.

Khouvine, Ephrussi and Chevais([4]) have given *v* and *cn* larvae food containing the extract of pupae of *Calliphora*; the effect of the extract was proportional to its quantity. With still greater exactitude such a dependence was demonstrated by Tatum and Beadle([3]) who injected to larvae *v* and *cn* various amounts of an extract of normal pupae of *D. melanogaster*.

In carrying on work in this field we have discovered a phenomenon which was not observed by the writers cited above; we therefore venture to publish our results.

The $\overset{+}{cn}$ and $\overset{+}{v}$-substances were introduced to the larvae exclusively with the food. As a source of these substances served normal pupae at the age from 0 to 36 hours following pupation; larvae which had already creeped out of the food but had not yet pupated were used as well. A necessary number of larvae or pupae were taken from the walls of the vial, ground in a china mortar, and a definite amount of the resulting pulp was put into a vial of 2—2.5 cm diameter which was overpopulated by larvae of the genotype

w^e*cnb* or *w*^{e}*vf*, 48—72 hours of age. The effect could be detected when working simply with the *v* or *cn* larvae, but it was more difficult to estimate than in the case of *w*^{e}*v* or *w*^{e}*cn*. The effect of the $\overset{+}{v}$ and $\overset{+}{cn}$-substances upon the former consists in their bright red eyes losing their brightness; the latter have nearly white eyes, and the effect is expressed in that their eyes obtain a pink shade.

It should be noted, besides, that larvae of the genotype *w*^{e}*cn* are more susceptible to a given amount of the $\overset{+}{cn}$-substance than larvae *cn*. In our first experiments we estimated the effect qualitatively. The experience had shown, however, that such an estimation is by far too rough; we have applied, therefore, following Beadle, a quantitative determination. Flies which had an eye colour indistinguishable from that in the controls received the mark 0; if an effect could be detected they received the mark 1; the mark 2 referred to those which showed eye colour indistinguishable from *w*^{e}. All the intermediate shades between 1 and 2 were estimated by 1.1, 1.2, 1.3, etc.

In some of the experiments the larvae collected were crushed not at once, but after having been treated with high temperature(6). This was done in the following way: the larvae were placed into a small glass supplied with a ground cover and put for 2—3 minutes into boiling water.

The development of the larvae and pupae which served as a source of the $\overset{+}{v}$ and $\overset{+}{cn}$-substances proceeded at a temperature of 21—22°C.

½, 1, 2 and 4 g of crushed larvae and pupae of the *Florida* line were placed into viales containing *w*^{e}*cn* larvae. The eye colour of the imago developed from larvae which received 1 g of the pulp was most strongly shifted toward *w*^{e} while in those whose larvae were given 4 g of the pulp the eye colour was but very slightly modified toward *w*^{e}. This experiment was repeated twice with the same results. Larvae of the constitution *w*^{e}*v* were given in one case 2 g, in the other 4 g of the pulp made of larvae and pupae of the line *Florida*. The eye colour in flies which received 2 g was strongly shifted toward *w*^{e}, whereas in those which received 4 g the eye colour was but very slightly modified in the *w*^{e} direction.

In Table 1 are presented the results obtained with *w*^{e}*cn* larvae; the eye colour was estimated with the aid of the mark system. Here, too, an increase of the effect is observed parallel to the dosage; but after the dosage attains comparatively high values, the effect is reduced. In Tables 2 and 3 are given the experimental results obtained for normal larvae which were treated with boiling water prior crushing. The same regularity was observed.

In Tables 4, 5, 6 and 7 are presented the results of the experiments with «non-boiled» *Florida*-larvae. It should be added that the whole amount of pulp was put into some of the vials not at once but divided into portions.

It is typical of these results that when the experimental larvae are given a large dosage divided into portions, the effect is always stronger than in case it is given at once, although the total effect is again reduced.

In Table 8 are presented the results for *w*^{e}*v* larvae. The same relations may be observed.

The results of the following experiment are of special interest: 2 g of pulp made of crushed larvae and pupae of the *Florida* line were placed in a clean vial. A great number of young larvae were placed on it. Altogether 57 flies hatched; their eye colour proved to remain unchanged. In the control vial into which 2 g of pulp was added in the usual manner, 99 flies hatched; they were given together 104.5 marks. It is especially clear from this experiment that an excess of $\overset{+}{cn}$-substance always affects the formation of the pigment. In Table 9 are contained the results of experiments with «boiled» larvae. The results are much the same.

Table 1

Amount of pulp in g	0.250	0.750	1.250	5
Total number of marks	21	20.1	27.9	20.1
n	30	28	30	30
Average effect	0.72	0.71	0.93	0.67

Table 2

Amount of pulp in g	0.250	0.500	1	2	3	4	6
Total number of marks	31.5	84.9	63.4	62.6	38.5	70.1	37.7
n	31	69	54	54	36	67	45
Average effect	1.01	1.23	1.17	1.15	1.06	1.04	0.83

Table 3

Amount of pulp in g	1	2	5
Total number of marks	95.7	92.2	65.6
n	93	88	93
Average effect	1.02	1.04	0.70

Table 4

Amount of pulp in g	0.250	0.500	1	2	4	1 g, after 24 hours 3 g more added	1
Total number of marks	68.3	90.9	103.1	79.3	35.3	83	167.6
n	65	75	82	82	79	132	132
Average effect	1.05	1.21	1.25	0.96	1.44	0.62	1.26

Table 5

Amount of pulp in g	1	2	4	2 g, after 24 hours 1 g added, after 24 hours another 1 g added
Total number of marks	146.3	146.5	76.2	106
n	111	109	114	114
Average effect	1.31	1.34	0.92	0.92

Table 6

Amount of pulp in g	1.250	2.500	5	1.250 g, after 72 hours 5 g added	2.500 g, after 72 hours 5 g added
Total number of marks	140.9	135.6	29.3	94.9	114.1
n	107	108	106	80	108
Average effect	1.31	1.25	0.27	1.18	1.05

Table 7

Amount of pulp in g	1	5.500	1.5 g, after 24 hours another 1.5 g, after 24 hours 1.5 g added, after 24 hours 1 g added
Total number of marks	154.2	1.7	139.1
n	121	116	121
Average effect	1.27	0.14	1.14

Table 8

Amount of pulp in g	0.500	1	2	4
Total number of marks	122.8	112	109.6	80
n	89	83	90	90
Average effect	1.37	1.34	1.21	0.88

Table 9

Amount of pulp in g	2	5	2 g, after 48 hours 4 g added	2 g in a clean vial
Total number of marks	94.3	49.8	53. 7	11
n	86	85	76	56
Average effect	1.09	0.58	0.70	0.19

It clearly follows from the results presented above that a comparatively large amount of the $\overset{+}{v}$ and $\overset{+}{cn}$-substances leads to a decrease of the effect, instead of its increase.

Many instances are known in biology when a given factor in a small dosage stimulates certain processes, and impairs them when applied in great dosage. However, there is still no general explanation of these facts.

The fact described in the present paper is closely associated with the problem of antihormones worked out by Kollin ([7],[8]) and his followers. It clearly follows, indeed, from the work by Tatum and Beadle ([5]) that the $\overset{+}{v}$ and $\overset{+}{cn}$-substances are hormone-like in their nature. It is known that certain hormones lose their stimulating effect when they are introduced into the organism in excess. It may be thought by analogy that an introduction of great dosages of hormone-like substances $\overset{+}{v}$ and $\overset{+}{cn}$ leads to the production by the organism of antihormones $\overset{+}{v}$ and $\overset{+}{cn}$. It seems to us to be of little probability. We will not discuss here the theory of antihormones; it would suffice to point out that the results of some of the experiments contained in Tables 6 and 7 speak against the application of the antihormone theory to the explanation of the fact discovered. It may be seen from the corresponding data that in case the larvae $w^e cn$ are given at the beginning a small dosage which can produce a good effect and then after some time a comparatively large dosage is added, the effect becomes reduced; but it is always greater than in those flies whose larvae had received as great a dosage but at once. It should be noted, that when the great dosage is added 72 hour following the small dosage, the reduction of the effect is insignificant. These observations may serve as arguments against the antihormone nature of the phenomenon described above. If the antihormone $\overset{+}{cn}$ were formed under the influence of the $\overset{+}{cn}$-substance it should be formed in both cases and, therefore, the effect should be equal in both.

The facts described above are closely related to certain phenomena known in genetics. Aside from the hypomorphic mutations dealt with at the beginning of this paper, Muller ([2]) has suggested the idea of antimorphic mutations. These are such mutant allelomorphs whose accumulation does not lead to a reversion to the wild type but, instead, the difference between the mutant character and the normal one in further increases. If one takes the difference between the hypomorphic and antimorphic mutations to consist in the fact that the former are characterized by hypofunction of the gene whereas hyperfunction is typical of the latter, it becomes intelligible on the basis of the above facts why accumulation of genes having hypofunction leads to reversion to the wild type while that of genes with hyperfunction carries away from the wild type. In case of the $\overset{+}{v}$ and $\overset{+}{cn}$-substances they act in small dosages as hypomorphic mutations and in great dosages—as antimorphic ones.

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GENETICS

FREQUENCY OF POLYEMBRYONY AND CHLOROPHYLL DEFICIENCY IN RYE

By DONTCHO KOSTOFF

(Communicated by N. I. Vavilov, Member of the Academy, 8. VI. 1939)

The studies by Kappert(1) in *Linum* and those by Ramiah, Parthasarathi and Ramanujam(2) in *Oryza* showed that some plants developing from twin seedlings are haploids. Namikawa and Kawakami (3) raised adult plants from wheat twins and found haploid, triploid and tetraploid plants among those with normal chromosome numbers. Studies along this line were carried out more recently on a large scale by a number of investigators. I shall recall here those by Harland(4), Müntzing (5), etc. which also showed that polyembryony leads to euploid chromosome alterations.

At the present time we have good methods for producing polyploid plants (colchicine, acenaphthene, brom-naphthaline, brom-acenaphthene, ethylmercury-chloride, etc.), but no reliable methods for producing haploids (6). X-rays, abnormal temperatures and interspecific hybridizations seem to be less effective in this respect than polyembryony.

Haploids were reported in a large number of plants viable in highly inbred (homozygous) condition. *Secale cereale* is a cross fertilizer which «degenerates» when inbred, therefore haploids from this plant would usually be lethal or semilethal. I attempted to verify this deduction. To this purpose 27 020 grains of *Secale cereale* var. Viatka were sown in boxes with sand. The sand was marked 1×1 cm and then single grains were placed in each square cm half covered with sand. The seeds were watered regularly. Thus, we raised 20 393 seedlings from 27 020 grains. Among these seedlings we found 5 twins, one triplet and 27 albinos. All ten plants from the twins and two of the triplet that were studied cytologically had a normal somatic chromosome number, namely $2n=14$. We also grew 39 606 seedlings in sowing 53 780 grains of *Secale cereale*—derivatives from the interspecific cross *S. cereale*×*S. montanum*. Among these seedlings we found 32 twins and 7 albinos (table). Sixty plants of the twins had 14 somatic chromosomes, and one of them was a triploid(No. 38) having 21 somatic chromosomes. Six twin plants died at an early stage. Three of them were not studied cytologically. One of the diploid twins was a structural hybrid forming: 1) $5^{II}+1^{III}+1^{I}$, 2) $5^{II}+1^{IV}$ and 3) $6^{II}+2^{I}$, its twin plant being normal. The triploid plant formed a large percentage of abortive pollen, on the average 72% (July), 68% (September), 84% (October). Most of the pollen grains appeared usually in two when mature and studied in aceto-carmine preparations, one or both of the twin pollen usually proved abortive. When only one of the twin pollen was abortive, the viable twin pollen was much larger than the abortive one (Figs. 1 and 2).

Plants	Seeds sown	Seedlings grown	Pairs of twins found		Triplets	Albinos	
			number	%		number	%
Secale cereale var. *Viatka*	27020	20393	5	0.029	1	27	0.132
Secale cereale-like derivatives from *S. cereale* × *S.montanum*	53780	39606	32	0.08	—	7	0.0176
№ 2411 *Triticum vulgare*	23220	18275	4	0.021	—	—	—

During the first meiosis we found 0 to 5 trivalents, most frequently, however, 2, 3 and 4 trivalents were formed. The plant formed eight spikes, six of them had altogether 216 spikelets, i. e., 432 flowers. These six spikes

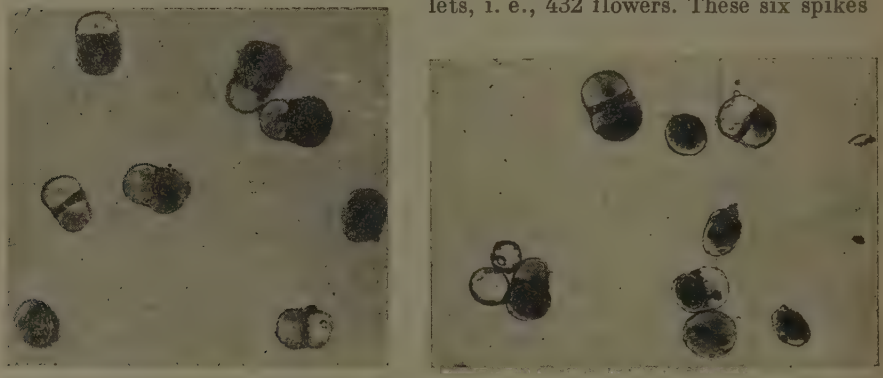

Fig. 1 and 2. Pollen from the triploid rye.

set 8 grains from free pollination, two of the grains being small, shrunken with bad embryos. They did not germinate. Two spikes were bagged. No seeds were set under the bags.

Along with the studies of polyembryony in rye, similar work was done in soft wheat—a plant that can be highly homozygotized without «degeneration» symptoms. We raised 18 275 seedlings from 23 220 grains of *Tr. vulgare* No. 2411. Among these seedlings we found four pairs of twins (table). Two seedlings of two different pairs were haploid ($n=21$), while the other six seedlings developed into normal diploid ($2n=42$) plants. Haploid plants were smaller than the normal ones. Their spikes were smaller. During the first meiosis we usually found in aceto-carmine preparations from one of the haploids 21 univalents or one bivalent and 19 univalents. In a few cells two bivalents were found. In a single pollen mother cell three bivalents were observed.

Out of 73 plants raised from rye twins and studied cytologically, only one triploid and one structural hybrid were found, but no haploids, while two haploids were raised out of eight wheat twins, i. e., 25% of haploids.

Until the present time adult haploids of *Secale cereale* have not been raised. Müntzing (7) obtained a semi-lethal haploid rye among the material treated by abnormal temperatures. Absence of haploids among the twins

studied by us is most probably due to the dying off of the haploids at an early stage of development, the diploid twins being only able to survive and grow further.

There is a good deal of speculations about the mode of origin of more than one embryo in a single ovule. When polyembryony is a sequence of nucellar embryony, the embryos, the seedlings and the plants that develop from them must be diploids with maternal genetic constitution. Twin embryos must also be diploid when they originate from two cells derived from the first cleavage products of the fertilized egg. When one embryo develops from the fertilized egg and the other from the endosperm, one diploid+one triploid twins may

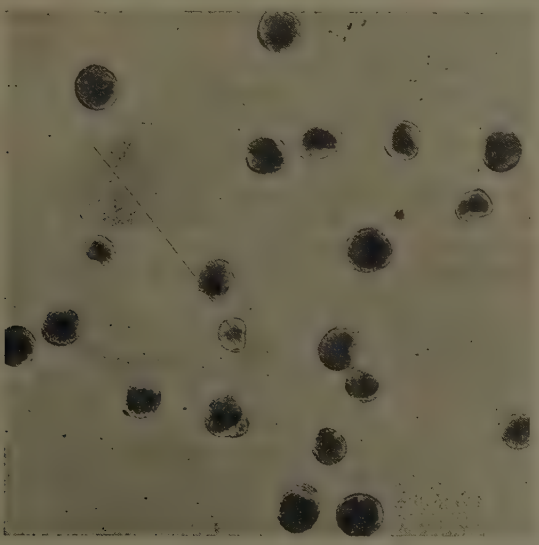

Fig. 3. Pollen from the structural hybrid raised from a twin pair.

originate. When one embryo develops from the fertilized egg and the other from a haploid embryosac cell (antipodal, for example), diploid+haploid twins will be formed. In the latter case it may happen that diploid+diploid twins develop if chromosome doubling takes place in the haploid embryo at an early developmental stage. Diploid+diploid twins or diploid+diploid+ +diploid triplets may also originate if two pollen-tubes penetrate the micropyle, the sperm of the one fertilizing the egg nucleus, while the other sperm fertilizes the polar nucleus and one or more than one antipodal nuclei. We do not know yet the mode of origin of tetraploid plants from twins and polyploids of a higher order. Fusion of antipodal cells and then polyspermic fertilization seem to be more probable processes than chromosome doubling in one of the pairs of diploid+diploid twins at an early stage of development, but the latter alternative is not excluded.

The twins of *Secale* studied by us do not seem to result from nucellar embryony because they differ morphologically.

The normal course of meiosis and normal fertility of the twin plant of the structural twin hybrid also supports this assumption. A structural hybrid formed about 50% of abortive pollen (Fig. 3) and was partly fertile.

Diploid+diploid *Secale* twins do not seem to result from diploid+ +haploid twins after a chromosome doubling in the haploid one at an early

developmental stage, because a diploid derived from a haploid rye by somatic doubling will be almost absolutely homozygous form, the latter being usually semilethal or lethal. The most probable origin of the twin seedlings I studied in rye seems to be: one arises from the fertilized egg and the other—from a fertilized antipodal cell, the triploid resulting, most probably, from an endosperm cell. It seems very probable that usually single plants develop from *Secale* twin diploid+haploid embryos, the haploid usually dying at an early developmental stage.

Polyembryony in angiosperm plants is a very common phenomenon. It is chiefly due, as a rule, to certain deviations in the developmental and fertilization processes in the embryosac. These lead to euploid chromosome alterations which are of great evolutionary significance, especially the tetraploid and the haploid with partial autosyndesis during meiosis. The frequency of the polyembryony in our experiments is very high. In the rye Viatka it is about one per 3500 and in *Secale cereale* derivatives—one per 1200. In wheat it was about one per 5000. The frequency of chlorophyll-deficiency (albino seedlings) in Viatka-rye was about one per 800 and in *Secale cereale* derivatives it was about one per 6000.

These figures point to an exceedingly high frequency of hereditary changes.

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GENETICS

TETRAPLOID PLANTS OF *VICIA FABA* PRODUCED BY COLCHICINE TREATMENT

By V. A. RYBIN

(Communicated by N. I. Vavilov, Member of the Academy, 3. VI. 1939)

In the first extensive communication on obtaining polyploids by colchicine treatment Blakeslee and Avery (1) mentioned among plants giving favourable results two belonging to the *Papilionaceae*, i. e., *Trifolium* and *Medicago*. It should be noted, however, that in the paper cited cytological proofs of the formation of tetraploid plants are given only for *Datura*. For most of the other plants, including *Trifolium* and *Medicago*, this paper records only the fact that these plants formed shoots with characteristic changes, enabling these investigators, with a high degree of probability, to regard them as chimeral with sectors of 4 *n* tissue. This was further confirmed by the formation by such plants of large (polyploid) pollen grains.

However, in a brief report published toward the end of 1938 by the Laboratory of Genetics of the Carnegie Institute (2), among 24 genera of 14 families, in which tetraploids were obtained by colchicine, neither *Trifolium* nor *Medicago* were mentioned at all. This circumstance indicates, apparently, that, despite obtaining chimeral plants with large (polyploid) pollen grains, Blakeslee did not produce tetraploid plants in either *Trifolium* or *Medicago*. The absence of representatives of the *Papilionaceae* in the Carnegie Institute list gives grounds for believing that the induction of polyploids in representatives of this family involves certain difficulties. It, therefore, seemed to the writer not devoid of interest to report the results of his experiments on treating *Vicia faba* with colchicine, since he succeeded in obtaining in this way two tetraploid plants.

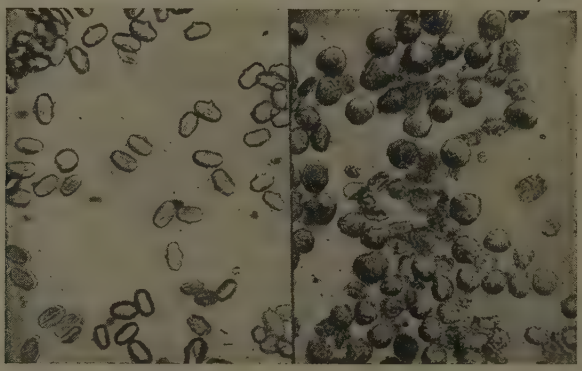
The material selected for these experiments was the small-seeded *Vicia faba* No. 1329, obtained from the Department of Grain Legumes of the Institute of Plant Industry. The plants were set out in small pots, two per pot, and after they had attained a height of 12—16 cm and had several pairs of well-developed leaves, they were immersed in a 0.1 per cent aqueous solution of colchicine. Before immersion in this solution the tips of the leaflets of the uppermost leaves were cut off with scissors, in order to facilitate the absorption of the colchicine by the plant*. The plants in the pots were kept well watered, and the upper surface of the soil was covered with cotton and a piece of parchment paper with two apertures for the plants. The edges of this paper cover were tightly bound about the rim of the pot. Then the

* This method is recommended by Blakeslee in the paper mentioned above (1).

pots were placed upside down on a wooden stand, under which was set a test tube with colchicine.

Not the entire plant was immersed in the solution, but only its upper part (approximately one-third or one-half). The temperature at the time of the experiments ranged from 20° to 23° C. The plants were kept in the solution for 18 hours. Upon taking the plants out of the solution there could be noticed an infiltration of the upper leaves. The colchicine solution had acquired the characteristic odour of crushed leaves or stems of plants belonging to the *Papilionaceae*.

Further observation of the plants under experiment revealed the following characteristic changes. The cut edges of the leaflets turned brown and died off. The plants were greatly retarded in growth, and after 15—20 days were only approximately half as tall as the control plants. Their stems thickened in a characteristic manner toward the tip which was composed of a unique rosette or cluster of leaves. This rosette was formed owing to the fact



Vicia faba pollen. Left—control plant; right—plant № 4; as viewed in a Leitz comparative microscope.

that the growing point kept on setting leaves, but the latter did not continue growth. At this time, on the lower part of the stem of the plants under experiments, there could also be noted buds, formed usually at the very surface of the earth or at the lower two or three nodes. The shoots which developed from these buds were either morphologically normal or bore altered leaves somewhat irregular in shape. The main stem gradually died away, and flowers were borne only on the shoots which had sprouted up from below and taken the place of the main stem.

One of the plants in pot No. 4, subjected to colchicine treatment on June 5 and flowering July 28, attracted attention by its dwarf habit and large (as compared with the control) flowers. The flower-bearing shoot sprang at the very surface of the soil, from the main stem which died away. As a result of the extreme shortening of the internodes, the flowers were so crowded that they seemed to form a single bunch. An examination of the pollen of the flowers of this plant in a comparative microscope showed that the pollen consisted of exceptionally large grains, differing also in shape from the pollen grains of the control plants (figure). Instead of being elongated-elliptical in shape as in the case of normal plants, the pollen grains of this plant No. 4 were globular, or angular globular. At the time of flowering plant No. 4 was infected with spotting, apparently of bacterial origin. Of the few flowers only two set pods. Each of the pods proved to contain but one

seed, and they did not attain full ripeness, since the plant, being unhealthy, died prematurely.

The two pods, together with the seeds, were dried in the laboratory. The seeds were considerably smaller than the control. On February 17 both seeds were placed in a Petri dish on moist filter paper. Their germination proceeded very slowly. In order to hasten germination, the Petri dish was placed during the daytime in a thermostat. After six days, i. e., February 23, both seeds sprouted, and put forth stout roots not over 3—4 mm in length. Cytological analysis of root-tips fixed in Navashin's chrom-acetic-formalin (10:4:1) solution showed that both plants had 24 as their somatic chromosome number, instead of 12 ([3],[4]), the normal number for *Vicia faba*, i. e., they proved to be tetraploids.

These tetraploids differ from diploid seedlings of the same age, as far as may be judged by observations during the first stages of development, by their thicker, slightly fleshy leaf blades, by broader and blunter leaflets of their compound leaves and by their slower growth.

The facts set forth in this paper are interesting in two respects. First, they show that representatives of the *Papilionaceae* react to colchicine treatment in the manner characteristic of other plants, which opens the possibility of experimental production of tetraploids in representatives of this family. Secondly, the data the writer has obtained from his experiments with *Vicia faba* fully confirm the correctness of his conclusions derived from experiments on producing tetraploids in flax ([5]). In the experiments with flax, just as in those with *Vicia faba* there was immersed only the upper half or even third of the stem, while the altered shoots giving rise to tetraploid seeds in both cases arose considerably lower, i. e., in a part of the plant which had not come into direct contact with the colchicine solution. This fact indicates presumably that the colchicine is capable of downward movement through the plant. It is characteristic that the useful, from the point of view of the experimenter, effect of colchicine (i. e., the formation of 4 *n* tissue) is manifested at some distance from the place of treatment, i. e. where the concentration of colchicine must be less than in those parts of the plant which were in direct contact with the colchicine solution. This fact should be kept in mind in work on producing polyploids by Blakeslee's method. In certain cases the possibility of the transmission of the action of colchicine over even a small distance may prove exceptionally important.

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GENETICS

FORMATION OF POLYPLOID FORMS IN *SOLANUM* SECT. *TUBERARIUM*

By V. I. IVANOV

(Communicated by N. I. Vavilov, Member of the Academy, 7. VI. 1939)

Dremlyug (4), Olah (5), Oppenheimer (6), Propach (7) and Nikolaeva [cited from Assejeva (1)] have recently demonstrated the formation of polyploid potato hybrids in remote hydridization. All the above writers note the rôle played by unreduced gametes (mainly from the maternal plant) in the formation of these polyploid hybrids. Rybin (8,9) points to a relatively common occurrence of unreduced gametes; he quotes both observations of his own and those of other writers. Such phenomena are evidently rather common in the sect. *Tuberarium* of the genus *Solanum*.

We shall dwell in this paper upon one of the instances. We have made a cytological analysis of the hybrids *S. Antipoviczii* × *S. tuberosum* and of the reciprocal combination. The material was obtained from F. F. Sidorov to whom my thanks are due.

F_1 *S. Antipoviczii* Buk. ($2n=48$) × *S. tuberosum* L. *Mirabilis* ($2n=48$).

S. Antipoviczii is a wild Mexican species; it is distinguished by its high resistance to phytophtora (10). It is taxonomically related to the *Longipedicellata* group (2) which is remote from *Tuberosa*.

Meiosis is comparatively normal. Berries are set well. Pollen consists to 80 per cent of good pollen grains. It presents difficulties when crossed with *S. tuberosum*. Whether this depends on taxonomical remoteness (3), on genome-incompatibility, or else on physiological causes, has not yet been established. We are inclined to think that physiological causes prevail here.

Mirabilis is a cultivated variety of *S. tuberosum*. Meiosis is slightly disturbed, especially at the anaphase stage of the I division. At the tetrad stage dyads and triads are found. The average proportion of normal pollen grains is from 50 to 60 per cent. Berries are formed but very rarely.

From the crosses only one F_1 plant was obtained: it proved to be resistant to phytophtora. In other characters, viz., colour of the corolla, leaf, growth habit etc., it was intermediate although reminded rather the wild form *S. Antipoviczii* than *S. tuberosum*. Cytological study has shown this plant to possess 72 chromosomes ($2n$, Fig. 1); one of the parental gametes should have been, therefore, unreduced.

In the majority of cases known to us unreduced gametes were contributed by the maternal organism. In our case the unreduced gamete probably belonged to *S. Antipoviczii* which was the mother. This is in sufficient accord with the morphological characters of the F_1 hybrids. Analysis of the F_2, F_3 and F_4 has shown that this hypothesis was correct.

Nikolaeva arrived at analogous conclusions from her studies on the hybrids *S. ajuscoense* × *S. tuberosum*. The study of the reduction division in F_1 hybrids has shown that it proceeded more or less normally but that there occurred anomalies at some stages. Thus, only 40 per cent of the I metaphase plates contained 36 elements (Fig. 2), a considerable proportion showing 37—39 elements; there were also found isolated plates with more than 40—42 elements or 34—35 elements. Evidently the 48 chromosomes of the doubled chromosome set of *S. Antipoviczii* have conjugated autosyndetically to form 24 bivalents, whereas the remaining 24 chromosomes of *S. tuberosum* either conjugated autosyndetically and formed 12 bivalents, or remained in part univalent. At the anaphase of the I division the chromosomes moved apart mostly at the same time, but sometimes there was lagging of 1—4 chromosomes. The second division had a more normal course, though tn this case, too, the elimination of 1—3 chromosomes could occasionally be observed (Fig. 3). At the tetrad stage, as a rule 4 cells were formed but instances of formation of dyads as well as triads and pentads were met with. The F_1 hybrid proved fertile although only 15—18 per cent of well filled pollen grains were found.

Fig. 1. Somatic chromosome plate of the F_1 *S. Antipoviczii* × *S. tuberosum* (2*n*=72).

F_2,F_3 and F_4 Hybrids. The progenies of the F_1,F_2 and F_3 were large and we have studied cytologically only a fraction of the plants. Some of them were studied by P. M. Mamulashvili.

The F_1, F_2 and F_3 hybrids were difficult to distinguish morphologically from one another and showed even greater resemblance with *S. Antipo-*

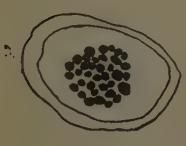

Fig. 2. Metaphase of the I division in the F_1 *S. Antipoviczii* × *S. tuberosum* (36 elements).

Fig. 3. Metaphase of the II division in the F_1 *S. Antipoviczii* × *S. tuberosum* (36—34 chromosomes and 2 eliminated chromosomes).

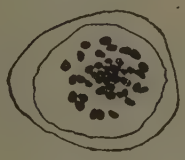

Fig. 4. Metaphase of the I division in the F_1 *S. tuberosum* × *S. Antipoviczii* (44 elements).

Fig. 5. Late anaphase of the I division in the F_1 *S. tuberosum* × *S. Antipoviczii* showing lagging univalents scattered along the spindle.

viczii than F_1. All of them were distinguished by a high resistance to phytophtora. In conformity with their morphological characters the hybrids proved to be constant with regard to their chromosome numbers. According to counts made by Mamulashvili and by us, the chromosome numbers in somatic cells of the meristem varied from 69 to 70. No good metaphases of the I division could unfortunately be found in anthers; however, meiosis probably differed here but little from that in F_1. At the I anaphase lagging of 1—5 chromosomes was also observed. The majority of the plates of the II division were regular (35+35), which is in accord with the somatic chromosome number; only occasional deviations were found. It may be assumed on the above grounds that nuclei with high chromosome numbers formed as a result of meiotic irregularities were unviable; otherwise plants possessing more than 72 chromosomes would have been formed. Nearly all the plants were fertile.

F_1 *S. tuberosum* L. × *S. Antipoviczii* Buk. Reciprocal hybrids were obtained in two combinations: *S. tuberosum Epicur* × *S. Antipoviczii*

(2 plants) and *S. tuberosum Narodny* × *S. Antipoviczii* (2 plants, one of which died).

The varieties *Epicur* and *Narodny* are completely sterile, the proportion of normal pollen not exceeding 2—3 per cent. Both the I and II meiotic divisions are highly abnormal. Lagging of chromosomes at anaphases, their elimination at the II metaphase, often in the number of 5—7 and even more, are common in these varieties. At the metaphase of the I division plates with 46—48 elements were met with, at the tetrad stage—dyads and even monads.

The hybrids were resistant to phytophtora. They were morphologically intermediate but resembled more to *S. tuberosum*; this was especially true of the two hybrids with variety *Epicur*. The somatic chromosome number in the root-meristem was equal to 72. An unreduced gamete thus was involved in this case, too. It was difficult to establish exactly which of the parents has contributed the gamete containing the double chromosome set. However, if one takes into consideration certain morphological affinity of the hybrids to *S. tuberosum* as well as the low rate of the 2*n* pollen tubes, one may assume that the unreduced gamete might be contributed again by the maternal plant — *S. tuberosum*.

Meiosis was irregular. We had no chance of finding a single plate of the I division showing 36 elements; on the other hand, those with 38, 39, 41, 44 and even with more elements were very frequent (Fig. 4). The anaphase of the I division also showed deviations which sometimes were considerable (Fig. 5). At the II metaphase regular plates could be occasionally met with, but more often the sister plates differed in chromosome numbers and great many of the chromosomes were eliminated into the plasm. The hybrids were sterile which probably was due to the effect of the plasm of *S. tuberosum*. None of the three plants formed berries, neither under natural conditions nor being artificially pollinated.

Rootlets and flower buds were fixed in Navashin's fluid (10 : 4 : 1). Prior to fixation of roots the potted plants were kept 6—8 hours on ice. The chromosomes were thus significantly shortened which made counting very much easier. Rootlets were sectioned 7 microns thick, flower buds—11—12 microns. Sections were stained with iron-haematoxylin after Haidenhain.

My sincere thanks are due to S. M. Bukassov, G. A. Levitsky and G. D. Karpechenko for their aid in the course of this investigation.

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PLANT PHYSIOLOGY

TRANSFER OF PHOTOPERIODIC REACTION FROM LEAVES TO GROWING POINTS

By B. S. MOSHKOV

(Communicated by N. I. Vavilov, Member of the Academy, 1. VI. 1939)

A number of theoretical questions is to be solved for making it possible to control the development and even the whole life activity of the meristem of one of the grafting components through the influence of the leaves of the other component. In 1936 V. G. Sokolovsky, while conducting his experiment under author's direction, was the first to show the causal mechanism underlying the phenomenon known as photoperiodic localization. If a large-flower chrysanthemum has been grown to bear two equal shoots and if one of those shoots is given 10-hour days as the other is given continuous illumination, then the first shoot will produce flowers and the second will not.

Similar results might naturally be expected in grafting, where one branch acts upon another. If indeed the development of growing points were not liable to other than external influence directly, there would be no grounds to suppose any disturbance of the localization.

One, however, who knows the rôle of leaves in photoperiodic reaction can hardly doubt that the transfer of the latter from one branch to another is possible and that grafting is a means to do this. As early as in 1935 the author started experiments in which *Nicotiana rustica* was grafted upon another species of tobacco, the latter being stripped of its leaves under conditions of continuous illumination. As to the above-mentioned experiment with chrysanthemum (1936), here the transmission of photoperiodic reaction from one branch to another was achieved by removing the growth points in the short-day branch and keeping the leaves of the long-day branch in darkness.

In that case the top of the branch under continuous illumination came to flower. Localization was broken too when the leaves had been stripped off from the branch instead of being held in darkness. The controls which had their both shoots under continuous illumination could by no means be induced to flower: neither by removing the leaves nor by keeping them in the dark; and it stands to reason that the result was negative too if the leaves were left on the branch to suffer with it continuous illumination.

It will be obvious that the leaves under continuous illumination prevent the growing points in the sphere of their influence to take part in the photoperiodic response of the short-day branch. Still more representative is the case when the photoperiodic treatment is applied to only one leaf from whose axil proceeds a shoot receiving continuous illumination. If the leaf is treated also continuously, the axillary shoot will not flower. If the leaf is given short days since the plant has been decapitated, the axillary shoot produces large buds as early as 24 days after the outset of treatment. If only half of the leaf is cut off, or placed in the dark and the other is given short days, flowering will set in at the same time as in the second set. When the case is reverse and one half is given continuous

illumination as the second half is given short days, the budding of the axillary shoot will be delayed for 20 — 30 days. This should be taken to mean that the processes which either accelerate or delay the effect of short days will not take place in the dark, but become operative on continuous illumination. Already in his earlier works the author was able to show that newly unfolded leaves are incapable of active response to photoperiodic conditions. Naturally enough, there arose the question as to the significance of such leaves in the protection of their dependent growing points from the influence of short-day leaves. The experiment to settle this question was arranged in the summer of 1937. Chrysanthemum plants were given continuous illumination until they attained a height of 20 cm. Then they were deprived of all their leaves and growing points except the third leaf from above with a bud in its axil. After this operation we placed the remaining leaf on a short day length, but not in all plants at once. There were several experimental sets and only the plants of the first set were subjected to short-day treatment immediately. Every two days a new set of plants was started suffering short photoperiods. In each set half the plants were deprived of the leaves which appeared on the shoot proceeding from the axil, while the others were not. The results of this test are given in the table.

Short-day treatment applied	Lateral shoot	
	With leaves	Without leaves
	Budding	
Immediately after decapitation	1.IX	1.IX
2 days later	9.IX	1.IX
4 » »	13.IX	3.IX
6 » »	19.IX 1 plant	9.IX
8 » »	No	13.IX
10 » »	No	19.IX

It is evident that an axillary shoot bearing leaves escaped the influence of the short-day leaf if the treatment had been started more than 6 days after operation. But no axillary shoot ever escaped this influence if it had been deprived of its leaves, since it invariably produced flowers under these conditions. This must be interpreted to mean that flowering is or is not induced in the axillary shoot under the action of the short-day leaf, according as the latter is made to act before or after the shoot has produced its own leaves. The transmission of the photoperiodic response from the leaf to the growing point, if it takes place, is very rapid. Thus, if the short-day leaf has been active during 10 days, it can be removed without affecting the formation of buds which will appear on the branch at the same time as in the plants in which the leaf is not removed and is given either short or continuous days.

The facts reported made the basis of another series of experiments conducted in the summer 1938. Two of them aimed at settling the following question: 1) are these reversible or irresersible processes which take place in the leaves of the short-day species under the influence of short days; 2) is it possible to make practical use of temporary grafting, in which the healing of the place of union would be of no importance. Both experiments were run with *Perilla ocymoides*, a southern plant. As stock in the first experiment were used the plants of perilla which after having attained an age of one month had been given short photoperiods during 20 days. The scions were tops from the seedlings of the same variety of perilla. All graftings were not made at once when the short day treatment of stocks was stopped. Every day new lots of scions and stocks were grafted, and this was being done during a period of two weeks to obtain a succession of experimental sets with increasingly distant start from the day of expiration of short photoperiods. Except for the 20 days mentioned above both the stocks and the scions were given continuous illumination throughout the experiment. All own shoots of the stocks which

would appear during short-day treatment or afterwards were removed as soon as they made their appearance. The result was that in all sets the scions were observed to start flowering on continuous day length in the time between 24 and 44 days after grafting. The fact that scion seedlings given only continuous light came to flower owing to the activity of the stock-leaves treated with short days is evidence of even so long a period of continuous light as a fortnight being unable to counteract the impulse imparted by the short-day treatment to the leaves, which did not lose their capacity to induce flowering in the growing points of the scions under their control. There was also a series of stocks in this experiment in which the leaves were removed at the moment of grafting just when they ceased to receive short days and these stocks gave no flowering scions. It will be obvious that no substance stored up in the stem of the stock may be considered responsible for the flowering induced in the scion. It is only the leaves which are endowed with the power to force the meristem into reproduction, and when no longer treated with short photoperiods they preserve this power during 15 days of continuous illumination. The photoperiodic after-effect may therefore be supposed to consist in that the leaves which have once enjoyed optimal photoperiodic conditions compel the growing points to reproduction under unfavourable conditions, too, if their activity is not counteracted by new forming leaves. If, however, the processes of growth point development are not complete before new leaves have been formed, they will never be so afterwards.

A top pair of unfolded leaves was borne by the scion, and not only were these leaves far from interfering with the influence of the stock, but they even enhanced it. The growth of the scions was delayed in their absence and accordingly the buds appeared later.

In the second experiment all stocks were grafted upon with seedlings immediately after the short day was replaced by continuous illumination. They remained for a varying length of time under the scions. The latter were then separated and allowed to root in the sand under continuous illumination. Every day a set of scions was taken from the stock into the sand and there were also 15 such sets in this experiment. They varied in the number of days which the continuous-day scions have passed on the short-day stock (1, 2, 3 etc. up to 15). It was only after 9—12 days on the stock that the grafts were observed to have taken when they had to be separated. In the sand all scions rooted well and developed into large plants. But only those of them produced flowers which had been kept on the stock more than 10 days. This means that 10 days of contact with the stock tissues were not enough for the photoperiodic induction of the stock to be transferred to the scions, and not until the tissues of both began growing into a whole, could the leaves of the stock fix their influence upon the growing points of the scion.

Author's surmise that the transmission of photoperiodic stimulus from the leaves of one component to the growing points of the other is possible merely by way of a close contact between their tissues has found no support in his observations. Needless to say that a transmission of this stimulus through some intermediate matter, as it is the case with the translocation of growth hormones, is still less probable. A direct and complete physiological union between the leaf and the growing point appears to be indispensable for the latter to develop under the influence of the former, and in case such a union is prevented by a premature operation or interfered with by formation of new leaves which come to control the growing points lying in their sphere of action, no transfer of photoperiodic stimulation becomes possible.

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PLANT PHYSIOLOGY

PLANT'S RESPONSE TO SHARP VARIATION OF TEMPERATURE

By O. A. GASHKOVA

(Communicated by A. A. Richter, Member of the Academy, 4. VI. 1939)

Evidence accumulated by the practice of growing thermophile plants is not in favour of abrupt changes in temperature, since there are many indications of plant being liable to «catch cold» in that way whether under in-door or out-door conditions.

The author himself has observed this effect on tomatoes cultivated in the fields of the Gorky Province. If temperature turned cold by night after it was warm or even hot by day, flowers and fruits fell in great number, and eventually the yield was strongly reduced.

This phenomenon being not satisfactorily studied and very important practically, we deemed it wise to investigate its physiological side and to compare the results obtained with the available data and with similar phenomena occurring in nature.

Systematic observations of the effects of a sharp variation of temperature do not appear to have been made, but interesting facts on the subject have been reported occasionally by various workers.

The present work was conducted by the Institute of Plant Physiology, Academy of Sciences of the USSR, in the summer of 1937, the author being guided by the consultation from A. Richter and K. Sukhorukov.

The plants involved in the experiment were tomatoes *Solanum Lycopersicum*, variety *Humbert* at an age of 2 months, lemon *Citrus Limonum*, 3 years old commercial variety from Batumi, tobacco *Nicotiana tabacum* v. *macrophyllum* at an age of $1^1/_2$ month and tobacco *Nicotiana rustica*, 2 months old. All plants were kept in a hot-house in darkness at 21°—25°C. They were subjected to sharp variaton of temperature when cut and kept dipping into water in an atmosphere saturated with water vapour.

To obtain light cooling chamber, we used glass jars placed into broad glass vessels filled with water and ice. If the temperature of the surrounding air was 25°C, that in the jars could be brought down to a stable range of 5—8°C by adding ice to the water.

The direct aim of the experiment was to determine how the viscosity of the plasma and the rate of photosynthesis and respiration in plants are affected by abrupt changes of temperature and to follow the further development of plants so treated.

Viscosity of Plasma. It is beyond any doubt that the rate of a number of processes taking place in a cell in connexion with the movement of various substances is dependent upon the viscosity of plasma (²), which

is very sensitive indicator of protoplasmic condition ([7]). It is reduced when growth processes are taking place and increases as the organism passes the state of anabiosis; it would seem that a more stable condition is reached by the cell by way of increased viscosity of the plasma ([3],[5],[8]).

The plants to be tested for plasmatic viscosity were cut, kept at 25°C and immediately taken into the chamber with 8°C. The centrifugation method of Weber([6]) was used in determination. It was the leaf-stalks which were centrifuged; the displacement of plastids was estimated on cuts, which were quickly made by hand in the cortical cells.

Now let us proceed to the discussion of the results obtained.

T o m a t o e s. The cut off plants were allowed to stand in water at 25°C; some of them were left there as control, while other were transferred to suffer a temperature of 8°C. The plants taken into cooling chamber, were centrifuged at intervals, and the displacement of plastids was followed.

The effect of the treatment was sharply to decrease the viscosity of cell's plasma during the first 30 minutes. But with 60 minutes elapsed a sudden increase was observed and the viscosity of experimental plants became 16 times that of controls.

The readiness with which the plastids shifted in the cells of rapidly cooled tomatoes during the first period of treatment was stated also in the case when the centrifuge was not put into operation, and it was only by slightly shaking the plants that the plastids were brought, according to Stokes' law, into the lowest position in the cell.

L e m o n. The experiment was conducted in a quite similar way.

The course of changing viscosity in lemon was quite identical with that in tomato—a sharp decrease during the first 30 minutes followed by a sudden increase.

The data for *Nicotiana rustica* were obtained by the same procedure.

The viscosity of plasma in *Nicotiana rustica* is much higher than in tomato or lemon. After the temperature had dropped the viscosity kept decreasing and no its increase was observed during the 40 minutes of treatment.

Similar results were obtained with *N. tabacum macrophyllum* except for a more rapid decrease in viscosity.

Sharp variation of temperature tends to change the protoplasmic quality of the cells, the viscosity of their plasma. The course of changing viscosity is not the same in tomato and lemon as it is in tobaccoes. In the former a sharp decrease in viscosity of the plasma was followed by a sharp increase, while in the latter the viscosity was decreasing throughout the period of observation (40 minutes).

P h o t o s y n t h e s i s a n d R e s p i r a t i o n. The changes occurring in the plasma are surely not without influence on the life processes of the organism. We have traced the course of photosynthesis and respiration under the same temperature variations that were inducing changes in the plasma. Gas metabolism was determined in the air current with Richter's absorber ([4]) and the leaf chambers of his construction; the use of these chambers made it possible to determine the photosynthesis and respiration at varying temperatures under conditions of a water thermostat. According to the experimental conditions, the tests for gas metabolism lasted 15 min. invariably; the amounts of carbon dioxide assimilated or evolved by respiration were recalculated in mgs to 1 m^2 of leaf area and 1 hour.

The temperature in the chambers was indicated during the experiment by mercury thermometers.

The results for tomato and *Nicotiana rustica* showed that both photosynthesis and respiration are differently affected by the drop of temperature

in tomato than in *Nicotiana rustica*. Rapid cooling of tomato leaf calls forth considerable increase in the rate of photosynthesis during the first minutes; this falls within the period of decreased viscosity of plasma. With this time elapsed a sudden decrease is observed to a much lower value, which lasts through 24 hours. Respiration too is at first observed to increase considerably in response to cooling, but afterwards it goes down abruptly and its value after 24 hours will accord with long established relation between the rate of respiration and temperature (1). In *Nicotiana rustica* the rate of photosynthesis is markedly reduced during the first minutes of cooling, then it goes up to a value which shows no change within 24 hours; the rate of respiration decreases gradually from the very start and onwards through 24 hours until it assumes a value normal for 8°C.

Now we see that the changes taking place in the plasma are peculiarly reflected by the run of certain life processes.

Observation of Plant's Development. The plants of tomato and *Nicotiana rustica* were repeatedly transferred from normal (25°C) to reduced (4°C) temperature. This treatment lasted 45 days. The controls enjoyed normal temperature in the green-house throughout the experiment and were given the same conditions of light as the experimental plants. All plants were 1 month old potted seedlings which had not yet started budding. The plan of the experiment and the main data are referred to in the table.

Green Growth and Flowering in Tomato and *Nicotiana rustica* as Affected by Temperature Drop from 25° to 4°C

	Hour treatment applic. × times	Intervals between treatments	Stem elongation after 45 days (average for 10 plants)	Behaviour of plants
Tomato	3 hours×3 times	15 days	11.5 cm	Flowering set in earlier in experimental plants but the flowers were partly shed. No visible depression of growth
»	12 hours×2 times	22 »	12.2 »	Earlier flowering resulted in shedding of all flowers. No depression
»	3 hours×8 times	5 »	10.7 »	Most of the flowers were shed after earlier flowering. No depression
Control 25°	—	—	14.6 »	Flowered normally and set ovaries
Nicotiana rustica	3 hours×2 times	22 days	10.0 »	Controls and experimentals flowered simultaneously and no difference was noticed between them
»	12 hours×2 times	22 »	8.0 »	Simultaneous flowering. Depression of growth in experimentals which had however better developped leaves
»	8 hours×8 times	5 »	25.0 »	Simultaneous flowering. Experimentals exceeded the controls in green bulk leaf development. Deep green colouring
»	12 hours×8 times	5 »	26.2 »	Do
Control 25°	—	—	14.6 »	Normal flowering and fruiting

It will be obvious that the different response of tomato and *Nicotiana rustica* to a sudden drop in temperature becomes apparent not only in the condition of the plasma and in the rate of assimilation and respiration, but it also extends over the behaviour of the plant as a whole. The tomato plants respond to decrease in temperature by shedding their buds and flowers and fail to change their green bulk appreciably while the plants of *Nicotiana rustica* flower normally, set fruits and considerably increase in green bulk under these conditions.

The conclusions to be drawn from the results obtained are as follows.

Abrupt change in temperature considerably affects the condition of the plasma in the cells and the rate of photosynthesis and respiration. The first response of thermophile plants (lemon, tomato) to cooling is strongly to decrease the viscosity of the plasma and this can possibly lead to passive translocation of plasmic formations and inclusions whose new position in the cell becomes fixed by the subsequent increase in the viscosity of the plasma. The rate of photosynthesis and respiration is enhanced by cooling, but also only for a few minutes and a pronounced decrease is soon observed to take place. In plants resistant to variation of temperature, as tobaccoes are, the effect of a sudden decrease is gradually to reduce the viscosity of the plasma, while the rate of photosynthesis is reduced only for a short time whereupon its steady increase sets in and is attended by a gradual fall of the respiration rate.

The abrupt increase of plasmic viscosity in the assimilating cells of thermophile plants should naturally disturb the outflow of organic matter and seriously interfere with a normal nutrition of reproductive organs. This will result in a premature fall of flowers and fruits which is often observed in practice and was induced by the author experimentally.

In plants of tobacco type the variations of temperature decrease the viscosity of the plasma. But this change in plasmic condition is known to be primarily involved in the process of growth ([5]) and is a factor accelerating the movement of various substances through the plant. The positive influence of temperature variation has been reported by many workers for a number of plants and our experiments with tobacco have furnished further evidence in support of this fact.

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PLANT PHYSIOLOGY

DOUBLE SUPPLY OF ENDOSPERM TO SPRING WHEAT SEED EMBRYO

By P. I. GREKOV

(Communicated by N. I. Vavilov, Member of the Academy, 4. VI. 1939)

The object of the present work was to establish what effect upon the growth and development of spring wheats would be brought about by supplying the seed embryo with increased (double) amount of endosperm as against the normally available in a spring wheat seed.

Ever since the beginning of last century a number of workers have been studying the growth and development of cereals in connexion with the amount of endosperm in their seed, but it was only the deficient amounts which were thereby considered. Dupetit, Sachs, Blociszewski, Brown and Morris, and others made the cereal embryos germinate with only a fourth or a half of the normal amount of endosperm in the seed, and also embryos provided with nothing except scutellum, and followed up the development and growth of the plants thus produced. Linz, Brown and Morris, Andronescu, Baker and Hulton, etc. separated the embryo from the endosperm in a cereal grain and grew it on various culture solutions.

Those experiments have brought into evidence that an embryo supplied with a deficient amount of endosperm (a fourth or a half of its normal quantity) is still capable of developing into plant. If however the embryos are separated from the endosperm and allowed to germinate in a warmed soil, they develop seedlings which produce leaves and several centimeters of root, but perish as early as in a few days. On the other hand, the experiments have shown that the endosperm can be replaced by culture solutions. The cereal embryo, if supplied with adequate nutriment, requires no endosperm for successful development(1).

Boussingault in his classical experiment by ascertaining the proportions between various substances in the seed endosperm and in the seedling of India corn has shown the relative importance of different endosperm fractions for growth and development of the embryo.

The group of unaccounted for substances in the experiment of Boussingault has recently been found to contain vitamins and phytohormones, both very important factors in the development of plants.

It should be noted that nature imposes limitations upon the amount of substances which are stored up by the parent plant in the seed to provide the embryo with sufficient nutrient material for the first period of its independent life. A spring wheat seed contains about 0.024 to 0.036 of endosperm.

The question arises here: what will be the growth and development of cereal plants, spring wheats in particular, if the amount of endosperm available for embryo nutrition exceeds, say, twice the normal.

We arranged a vegetation experiment to clear up this question. The spring wheat varieties involved were: *Novinka*, *Caesium* 0111, *Milturum* 0321, *Erythrospermum* 0341, *Hordeiforme* 010, *Lutescens* 062 and *Strube*.

Two seeds fulfilled different rôles in the test. One of them was left with its embryo; from the other the embryo was removed, and with it the scutellum, by a cut which gave a slant surface. The seed with the embryo was glued to that surface; for better sticking it also had a slant cut made on the side of union. Now we had one embryo supplied with a double store of endosperm from two seeds. Gluing was made with wheat flour turned to paste by adding hot water.

The grounds underlying this method of coupling wheat seeds are as follows:

1) With the imbibition of water the enzymic activity is initiated throughout the grain and does not depend upon the presence or absence of scutellum and sprout. Accordingly, the amylase and maltose will split up carbohydrates in the second seed as in the first. The lipase, phosphotase and the other enzymes splitting up fats, the group of protealytic enzymes affecting proteins and the oxidizing enzymes, as oxidase and peroxidase, all will be awakened to operate in both seeds simultaneously.

2) Flour diluted to paste with water was used in gluing the wheat seeds and this is the same material of which the endosperm is made. Moreover, the gluing layer of flour is no obstacle for the nutrient substances formed through the agency of enzymes to pass from the second seed to the embryo in the first seed.

3) Evidence produced by Brown, Morris and Stingl is that embryos removed from the endosperm of their seed and grafted intra- or inter-specifically upon the endosperm of a foreign seed will grow and develop there.

We started with some experiments of preliminary nature in which seedlings from coupled and normal seeds were subjected to observation. Germination was taking place on a paper filter and in vessels with sand. The results were as follows.

1) In most of the cases the coupled seeds were ahead of the normal ones of the same variety. They were earlier in both sprouting and rooting.

2) Some of the coupled seeds produced 5 roots at once, instead of 3, on germination. This was not observed with normal seeds, which had moreover their smaller number of roots emerged later.

3) The sprout growth was more vigorous in the coupled than in the single seeds. The former had longer sprouts though their roots were sometimes shorter than in the latter.

4) It has been definitely established that the nutrient substances of the second seed in a couple move into the first seed to feed the embryo. As the seedling grows, the second seed is gradually emptied while the first remains full. The empty space in the second seed grows from the side opposite to the surface of union. The nutrient substances pass through the gluing meal to the first seed.

Then we arranged a vegetation experiment. The first set of tests was conducted in Wagner's vessels, two vessels being taken for each variety: one containing 12 coupled seeds, the other—12 normal seeds. The second set was started 10 days later in Mitcherlich's vessels. Only 5 spring wheat varieties were involved in it: *Novinka*, *Caesium* 0111, *Strube*, *Milturum* 0321 and *Lutescens* 062.

The nutrient area was larger in Wagner's than in Mitcherlich's vessels, and the plants of the first set developed better. In all cases the seedlings from the coupled seeds appeared above ground earlier than did the seedlings of the normal seeds. The difference was 3—4 days in varieties *Novinka* and

Caesium 0111; it was 4—5 days in *Milturum* 0321 and *Strube* and amounted to 5—7 days in *Erythrospermum* 0341, *Hordeiforme* 010 and *Lutescens* 062.

During vegetation the plants from the coupled seeds were always ahead of those from the normal seeds in growth and development. The couple-seed seedlings had three leaflets as against one or rarely two leaflets borne by the normal-seed seedlings.

The difference between these two kinds of plants was especially conspicuous at the time of heading and flowering. The couple-seed plants sooner came into ear and their flowering was complete 6—10 days earlier.

At that phase of development the greatest difference was shown by *Hordeiforme*. When its experimental plants had passed to the stage of first ripeness, its controls were only coming into spike. Respectively the controls of *Erythrospermum* 0341, *Strube*, *Caesium* 0111 and *Milturum* 0321 had already produced ears when the experimentals were passing to the stage of first ripeness. The stage of complete ripeness was attained by the experimental plants 8—15 days earlier compared to the controls. The most representative in that respect were *Hordeiforme* 010, *Erythrospermum* 0341 and *Strube*. The plants were considered completely mature when their grain was perfectly hard and no green tissue remained on the stem and leaves.

All the varieties tested responded to the increased supply of their seed embryo with endosperm by strengthening their constitution which can be characterized by two principal indices: mean stem height and mean total weight of stem, leaf and spine membranes.

The difference in the mean weight of the stem varied between 3.1 and 26 cm, 4.7 and 42% respectively.

Stem height difference was greatest in *Hordeiforme* 010, *Erythrospermum* 0341 and *Strube* (32—42%) while it was only 4.7—7% in *Novinka* and *Milturum*. The mean total weight of stem, leaf and spike membranes showed nearly the same relation between the varieties with the single exception of *Milturum* 0321 which ranked here comparatively high.

It will be apparent that the increased supply of endosperm to seed embryo proved to have a positive influence upon the general constitution of plants.

The grain yeild was also affected favourably by this factor as is seen from the mean number of grains per spike and the mean weight.

The plants from coupled seeds yielded more grains, from 2 (*Caesium* 0111) to 6 (*Milturum* 0321). Their large number of grains per spike and better development resulted in a high yield, i. e. high average weight of grain per one spike (from 25 to 30%).

The total yield, i. e. the average weight of both grain and green parts, was also higher in the experimental than in the control plants. Here the difference between the former and the latter was 13 to 48.6%.

Among the experimentals of *Novinka* two specimens stood out by the height of their stem and especially by the size of the spike and the number of grains in it. One had 45 grains, the other 40 grains, while the rest of plants ranged in grain number between 25 and 27.

We reach now the conclusion that if the seed embryo of spring wheat is supplied with double amount of endosperm, the seedlings appear above ground earlier and the further development of plants is accelerated. Another effect of enhanced nutrition is to increase the height of the plants, their weight and grain yield.

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PLANT PHYSIOLOCY

DEVICE FOR DETERMINING LEAVES AREA

By E. G. PETROV and N. I. GAVRILOV

(Communicated by A. N. Bach, Member of the Academy, 5. IV. 1939)

In physiological investigations it is frequently necessary to determine the area of leaves. The leaf, as an organ in which the most important biological processes take place, has been the subject of numerous scientific investigations. The study of photosynthesis, respiration and transpiration require determination of the area of the leaf surface. However, the methods of determination are as yet far from being perfect and the procedures are so laborious that the investigator is often forced to renounce to the solution of some important problem on account of the difficulties involved in the determination of the leaf area.

The method found by us, we believe, will make it possible to apply in further investigations to a larger scale the estimation of the leaf area, when evaluating productivity of photosynthesis per unit leaf area, as well as respiration and transpiration processes. Moreover, the method found by us permits of studying the increment of leaf surface area, if necessary, without cutting off the leaves, thus observing the dynamics of growth of the leaf area on one and the same plant by means of repeated measurements.

The methods of determination of leaf area usually applied consist in reproducing the leaf's outline on a sheet of paper and in determining the area thus reproduced either by gravimetric method, or with the aid of a planimeter. The outlines of a leaf on a paper sheet are obtained either by tracing them with a pencil, or else the imprint of the leaf is obtained on sensitive paper. The pencilling-method is most cumbersome and subject to considerable inaccuracy. The more accurate method of obtaining imprints on sensitive paper is twice as laborious. Besides both methods require, as a rule, the leaves to be cut off, which excludes the possibility of repeated observations on one and the same plant.

The apparatus devised and applied by us has for its basis the principle of photometry. If one takes a small chamber (box) with one of its walls made of glass, and places it under a constant source of light, the intensity of illumination inside the chamber will be determined by the area of its transparent wall. This intensity may be easily evaluated with the aid of a photoelement which, being placed within the chamber, will cause a corresponding deviation of the galvanometer's hand. If, further on, an opaque object, say, a leaf, be placed against the transparent wall, thus preventing light to penetrate into the chamber, the intensity of illumination within the chamber will decrease, which will be recorded by the galvanometer. Hence it is possible to find out the relation between the area of the shading object and the degree

of the hand's deviation, i. e. to calibrate the chamber. The calibrating curve will make it possible to determine the area of the shading object (leaf) after the graph. To do so it is necessary to find the difference between the readings on the galvanometer with and without a leaf acting as a screen.

Such is the mechanism of the action of the apparatus to which we gave the name of «photoelectric planimeter» (Fig. 1).

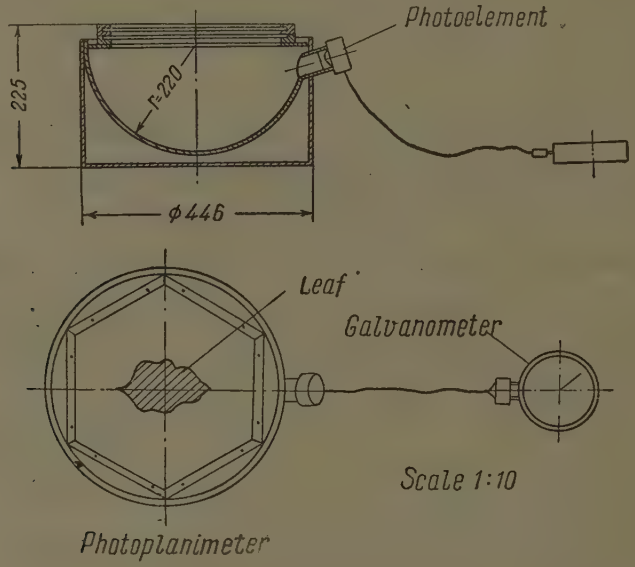

Fig. 1.

Moreover, the photoelement failed to measure the total light penetrating into the chamber, recording only the refracted part of it falling on the working surface of the photoelement. Its use therefore required a thorough mixing of the light-flow which was achieved by us by means of creating within the chamber a spherical mat white surface.

To eliminate the transparency of the leaf transmitting yellow and chiefly green rays, before the photoelement there is placed a blue-violet light filter of due density. The apparatus is operating under day-light illumination; to control light intensity, in front of the photoelement is placed an ordinary iris-diaphragm from a camera. The use of a selenium cell working without being fed from a battery proved the most expedient. A vertical galvanometer with a sensitivity of 10^{-6} amperes is applied.

Our apparatus was devised to measure the leaf area of sugar beet. It is mounted in a portable cylindrical box. The galvanometer has a separate case. The frame for fixing of leaves is supplied with a double thick glass; the leaf is placed under the upper glass by whose weight it is pressed to the lower one.

To hand the apparatus, calibrating curves were obtained at different daylight intensities (Fig. 2). Each of the curves corresponds to the readings of the galvanometer's hand. According to the intensity of illumination, the operator choses one of the curves, fixing the galvanometer's hand by means of the diaphragm at the due mark (the frame being unshaded) and proceeds working until light conditions are visibly changed.

A test of the apparatus for accuracy has shown that it somewhat exaggerates the area determined. However, the error is so small that it does by

no means discredit the device. The inaccuracy of the planimeter is characterized by a mean error equal to+1.1%; the exactitude of the readings may be improved by introducing due correction.

We find the degree of accuracy attained quite satisfactory. Comparative

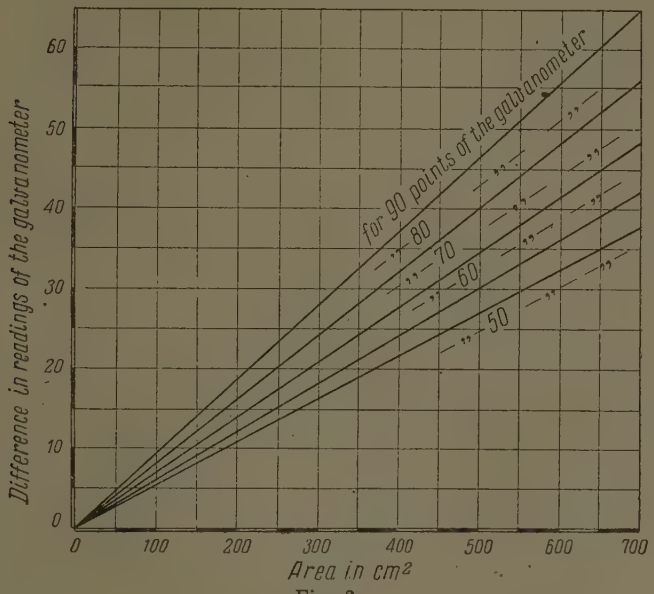

Fig. 2.

measurements of areas made with the help of a photoelectric planimeter and by other methods gave the following results:

	Procedure of measurement		
	Outline pencilling with the help of a planimeter	Cutting out of the outlines and gravimetric determination of area	Measurement by means of photoelectric planimeter
Total area of 100 leaves in dm^2 . .	136.304	145.967	139.420
Mean measurement error in % . . .	—1.15	+5.86	+1.10
Time expenditure in hours	10 h. 41 min.	9 h. 32 min.	1 h. 27 min.

Neither accuracy, nor rapidity of measuring is affected by the complexity of the leaf's outline. Small leaves may be measured several at once, which will only accelerate the process, while other methods being used this circumstance considerably complicates the procedure of measuring.

The outlays are mainly composed of the cost of the galvanometer, the photoelement, the iris diaphragm and the chamber. To the drawbacks of the apparatus belongs its unwieldiness which however the authors hope to eliminate in the next future.

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PLANT PHYSIOLOCY

EFFECT OF COLCHICINE FROM *COLCHICUM UMBROSUM* STEV. ON THE CAMPHOR BASIL

By V. GLOTOV

(Communicated by A. A. Richter, Member of the Academy, 5. VI. 1939)

After the appearance of the work by Blakeslee and Avery (1937) the practice of production of tetraploids became such a simple affair that tetraploids have been already obtained in the majority of economically valuable crops. Colchicine has been successfully applied also to overcome the sterility in remote hybridization, through doubling the chromosome numbers.

The colchicine usually applied for this purpose is that prepared from *C. autumnale*; it was not manufactured either in prerevolutionary Russia or in the Soviet Union. The great interest to this drug which arose among geneticists and cytologists resulted in the consumption of the old supplies in scientific institutions and drug-stores.

The All-Union Institute of Medicinal Plants has therefore taken measures to find sources of colchicine in this country.

C. autumnale does not grow wild in the Soviet Union. We turned therefore to the study of other species of *Colchicum* and particularly of *C. umbrosum* which grows wild in sufficient amounts at the Crimea and Caucasus, in the foothill and mountain subalpine and forest zones. According to the literary data *C. umbrosum* contains about 0.1 per cent of colchicine in dry bulbs while *C. autumnale* contains about 0.2 per cent.

Bulbs of *C. umbrosum* were obtained in 1938 from Crimea and passed over to the Chemico-Pharmaceutical Institute for isolation of pure colchicine. The colchicine obtained did not differ in physical or chemical properties from the ordinary imported one. The only difference consisted in its somewhat lower melting point (125—130°C instead of 139—145°C); this should probably be put down to impurities which amounted to 31.8 per cent. The chemically pure colchicine is highly soluble in water; the product in question left an insoluble residue of yellow colour. It was easily soluble in alcohol and completely insoluble in ether or xylol. Such an amount of impurities might surely have affected both the melting point of our colchicine and its biological properties.

Experiments on the biological effect were conducted in the spring 1939 by the Cytological laboratory of the All-Union Institute of Medicinal Plants. As a plant object-indicator served the camphor basil. As shown by our experiments of 1938, this plant is highly sensitive to slight changes in concentration of colchicine and, which is the most important, permits of easy diagnosis of polyploids by external characters and, besides, at an earliest age.

In young seedlings which were subjected to colchicine treatment the hypocotyle usually becomes highly thickened which is the first sign of the effect of this drug; great retardation of growth is observed. The cotyledon stage thus lasts in some of the seedlings 100 days; then either death ensues (which is of more common occurrence) or true leaves are formed and the seedlings develop into mature plants. The few surviving plants exhibit further strong morphological changes characteristic of polyploid forms: great thickening of the leaf-blade, crimping or convexity of the leaf-surface; intense green coloration of the leaves and thickening of the stem. All the previous works of 1938 allow to take for established the correlation between external changes obtained as a result of the action of colchicine and the internal chromosome set. We decided therefore to publish the data on the Soviet colchicine without awaiting the results of cytological analysis.

In this experiments we have adopted two most effective methods tried in 1938.

1. Seeds were grown in Petri dishes on filter paper moistened with solutions of colchicine containing 0.0063, 0.0031, 0.0015, 0.000075 per cent and «traces»* of the drug. Mass germination took place after 6 days and seedlings were planted into pots. The experimental plants were kept in a green-house at a temperature of 20—25°C. The experiment was started 9.III. 1939.

2. Application of drops of colchicine to the growing point. A 0.025 per cent solution was used, 30 drops being applied; there was also used a combined treatment with 30 drops of a 0.025 per cent solution followed by 50 drops of a 0.0063 per cent solution. Five drops were applied every day to the growing point at the time of formation of the first pair of true leaves. In order to prevent the flow down the stem and the rapid evaporation, the upper part of the stem was surrounded with cotton through which was attained longer contact of colchicine with the plant tisue.

It should be noted first that the germination power of the seeds was nearly the same in the Soviet or imported colchicine dissolved in distilled water. The average germination per cent was 77.2, 75.6 and 78.5, respectively; variation proved, therefore, to lie within the normal limits. The energy of germination was 5.9, 5.2 and 4.9 days, i. e. germination was somewhat dilated which should probably be accounted for by the presence of impurities; the energy of germination in imported colchicine was nearly identical with data of the control which was also the case in 1938.

The further development of the young plants can be characterized in the following way:

First, the Soviet colchicine produces the characteristic swelling of the hypocotyle analogous to that caused by the imported one, i.e. the specific effect of colchicine is present; secondly, the effect of the Soviet colchicine is somewhat stronger than that of the imported one in equal concentrations. The highest concentration at which root-hairs were formed was equal to 0.0031 per cent for the imported colchicine and to 0.0015 per cent for the Soviet one. Further, «traces» of the Soviet colchicine showed stronger effect upon the thickening of the hypocotyle as compared to the imported one. When seed were treated with colchicine, especially in higher concentrations, an extremely high mortality occurred; it attained in most cases 100 per cent.

The proportion of dying plants was somewhat higher in the case of the Soviet colchicine; this could be explained by the presence of harmful impurities.

The next stage, the occurrence of true leaves, was passed nearly parallel.

*The following concentration was arbitrarily termed «traces»: 5 drops of 0.025 per cent solution was added to 40 cm^3 of distilled water.

Large plants upon treatment with «traces» of colchicine had in both cases convex thick leaves which alone pointed to a change in the chromosome number. It should be noted that the convexity of the leaves was stronger expressed in the case of imported colchicine. The development of the plants was similarly stronger delayed by the imported colchicine. The plants which exhibited delayed development and depressed growth were nearly identical and possessed altered and thickened leaves. The control plants developed quite normally and showed none of the changes noted above. Inspection of the material thus showed full parallelism of the action of the Soviet and imported colchicine.

Out of the 13 plants treated with 30 drops of a 0.025 per cent solution of Soviet colchicine we had 3 wholly normal plants and 10 plants with swelling of the upper part of the stem, showing strong delay in growth and development, possessing strongly thickened and somewhat malformed leaves characteristic of the action of colchicine. On the other hand, among 15 plants treated with imported colchicine we had one normal plant and 14 with changes analogous to those described above, but somewhat stronger expressed. The effect of the Soviet colchicine was somewhat weaker, possibly again owing to impurities contained in it. Alternating the treatment with 0.025 and 0.0063 per cent solution the following results were obtained: out of the 3 plants treated with Soviet colchicine one died and the surviving two showed slight alterations; out of the 32 plants treated with the imported colchicine only 3 were slightly altered whereas the remaining ones showed strong alterations.

The principal conclusion is as follows: the colchicine isolated from *C. umbrosum* is physically, chemically and biologically (in respect to production of polyploid forms) identical to the imported one, prepared from *C. autumnale*.

Its only drawback consists in an extremely high content of some harmful impurities; one may evidently get rid of them without difficulty. We have started analogous work on other species of *Colchicum*.

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PLANT PHYSIOLOGY

MECHANISM OF AUXIN-FORMATION IN GREEN PLANT

By L. P. ZHDANOVA

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Plant physiologists have had exceptional interest for the study of growth hormones—auxins, and these are now the only vegetable hormones rather well investigated. However, the rôle played by various organs, leaves and growth points in synthesizing auxins is not yet clear.

The present work had for object to fix the place of auxin formation in the plant and to determine the rôle of leaves in this process.

The concentration of auxins was estimated on the basis of Went's technique. It was by way of diffusion that auxin was extracted out of the plant in most of the experiments. Stem tips 1 cm long with the terminal bud removed from them were placed with their lower surface on $0.6 \times 0.6 \times 0.15$ cm plates made of 3 per cent agar for 3 hours. This interval being elapsed the plate was cut up into nine small blocks of equal size and each one of them was placed eccentrically on a decapitated coleoptile of *Avena*. The curvature was measured 1.5—2 hours later. In determining the auxin content in leaves extraction was made by means of sulphuric ether. In the following tables the amount of auxin is expressed in degrees of coleoptile curvature. The figures are means of 8—10 estimations. The subjects of investigation were *Vicia faba*, *Hydrangea hortensis*, *Helianthus tuberosus*, *Chrysanthemum indicum* and *Nicotiana tabacum*, variety Trebizond 93.

The first tests aimed at establishing the place of auxin synthesis in the plant. In the specimens of *Hydrangea hortensis* bearing three nearly identical shoots one shoot was left uninjured and served as control, the second had its growth points removed and the third was deprived of its leaves. No translocation of auxin from one shoot to another was possible, since this is known to proceed in the basipetal direction only. Parallelly in another specimen of that plant all shoots were stripped off their leaves. 5—6 days later the shoot tips, 1 cm long, were tested for their content of auxin (Table 1).

The conclusion to be drawn from these data is that the synthesis of auxin will not take place in a green plant unless the leaves and the growth points are both involved in the process, in which, however, they have to perform different functions. No auxin was ever detected by us in a tip from a stem deprived of growth points. But it was present in the leafless shoot of a plant which had its other shoots with leaves and was not found in the plants in which all leaves had been removed.

These results gave ground for the assumption that auxin is produced in the growth points at the expense of the substances which are stored by the leaves and can freely travel through the plant in any direction.

The object of the further work was to show that the auxin stored by the leaves is largely that produced in the growth points. One month old plants

Table 1

Amount of Auxin in *Hydrangea* Shoot Tips with Reference to the Presence or Absence of Growth Points and Leaves

No.	Experimental conditions	19.IV	25.IV	5.V	9.V	1.VI
	Plant I					
1	The shoot with both leaves and growth points	7±0.92	13±1.85	11±3.46	12±1.67	10±1.18
2	The shoot with leaves, without growth points	0	0	0	0	0
3	The shoot without leaves, with growth points	6±1.47	19±2.00	11±3.87	12±1.50	10±1.08
	Plant II					
4	All shoots without leaves, with growth points	0	0	0	0	0

of *Vicia faba* were deprived of all their buds. Auxin was estimated 7—9 days later through extraction by ether from fresh samples of upper node leaves taken from both whole and decapitated plants (Table 2).

From these data it is obvious that the amount of auxin in the leaves is sharply reduced by removing the terminal and the lateral buds. This fact has been confirmed by observing the geotropic response of the leaves of *Hydrangea hortensis* and *Helianthus tuberosus* taken from whole plants and from plants decapitated 10 days before the start of the experiment*.

Table 2

Amount of Auxin in Leaves and Stems from Whole and Decapitated Plants of *Vicia faba*

Date	Weighed portion	Whole plant	Decapitated
1.VII	Leaves	23±2.20	2±0.94
9.VII	Leaves	8±1.48	2±1.07
9.VII	Stems (cut-off 7—10 cm long from the apex)	9±2.85	2±1.09

The cut-off leaves were placed in a horizontal position in the light and in the dark into humid exsiccators for 1 to 7 days (Table 3).

As is seen from the Table, the leaves from the whole plants show equal geotropic response whether they were kept in darkness or in light. The decapitated plants have produced leaves whose geotropic response is nearly zero since the leaves when cut-off for the experiment were already ranging in petiole curvature between 20—30°.

Avery ([2]) in his circumstantial work on the distribution of auxin in the young and the old leaves of Turkish tobacco has put forward the suggestion that auxin is produced in the leaves and flows down to the stem. His opinion is shared by several other investigators.

The evidence furnished by our experiment (Tables 2 and 3) is not, however, in favour of this statement, since it has shown the fully developed leaves to receive auxin from the buds. This observation finds further sup-

* According to literary data, the geotropism of leaves, as of any plant organ is due to unequal distribution of auxin on the upper and the under side. Du Buy ([4]) has found its value to depend upon the absolute difference in auxin content on the two opposite sides.

Table 3

Geotropic Response of Leaves from Whole and from Decapitated Plants of *Hydrangea hortensis* and *Helianthus tuberosus*, in Degrees of Petiole Curvature

Plant	*Hydrangea hortensis*		*Helianthus tuberosus*				
Duration of experiment in days	2	3	1	2		3	
Illumination / Plants	Daylight		Daylight		Darkness	Daylight	Darkness
Decapitated	28	27	28	28	20	26	30
Whole	81	75	134	116	84	147	138

port in the transport of heteroauxin in the leaf-blades of *Coleus* as reported by Laibach and Fischnich (5) who have found this substance to travel in any direction through living leaf-tissue. At the beginning we have shown that the leaves are largely involved in auxin production and it is therefore only natural to expect them to form the initial substances indispensable for synthesizing this substance, while they are being exposed to the light. The experiments along this line were started with studying the influence of varying light intensities upon the synthesis of auxin. Either the entire plants of tobacco and chrysanthemum or only their leaves were covered with 1, 3 or 6 layers of gauze. Auxin was estimated in the tips cut-off 1 cm long (Table 4). From the table it is evident that whatever conditions of light the tips may be given they invariably decrease in auxin with decreased intensity of illumination. This is in full accord with the results obtained by Avery and co-workers (3) who have studied the influence of artificial electric light of varying intensity upon the synthesis of auxin.

The above facts suggest that the formation of initial substances for auxin production is bound up with the photosynthetic activity of leaves. Corroborative evidence of this supposition has been afforded by the further experiments. The leaves of tobacco variety «Trebizond 93» and chrysanthemum variety «White Mary» were kept in the dark and given 0.2 and 0.4 mol. of glucose solution, respectively, by means of vacuum infiltration every day. This treatment was stopped 10—15 days later and the estimation of auxin made in the stem tips 1 cm long showed that it was present in the leaves treated with glucose, while no signs of its presence in the leaves treated with water could be detected.

The following experiments were arranged to clear up the question whether sugar may serve as initial material for auxin production in growing points. A 2% solution of glucose was introduced through glass tubes into the stem of leafless plants of *Hydrangea*. About 10 days later the amount of auxin in the stem tips was estimated. In two cases we found it to correspond to 7 ± 0.89 and 9 ± 1.24 degrees of average coleoptile curvature, respectively. In water treated controls no auxin could be detected. The evidence furnished by these experiments is that auxin is synthesized in the growing points out of the sugar as initial material.

The results of some experiments on cut-off tips go to confirm this conclusion. Apical leafless ends 2.5 cm long were cut off from the plants of *Vicia faba* and grown on glucose solution during 5—6 days. At the start of the

Table 4

Influence of Light of Varying Degrees of Intensity upon Synthesis of Auxin in Plants of Tobacco «Trebizond 93» and Chrysanthemum «White Mary»

Illumination of tips / of leaves	Tobacco			Chrysanthemum		
	2.VII—22.VII		27.VII—5.VIII	3.IX—19.IX		3.IX—26.IX
	*	Full daylight	*	*	Darkness	*
Full light	11±0.95	11±0.95	12±1.34	12±1.45	13±0.93	9±1.06
1 layer of gauze	12±2.12	12±2.02	12±2.82	11±1.03	9±1.34	11±1.41
2 layers of gauze	11±1.78	7±0.94	10±2.02	1	2±0.93	11±2.09
6 layers of gauze	3±0.81	0	0	3±0.95	2±0.90	4±0.41
Darkness	—	—	2±1.16	0	0	5±1.13

experiment they were known not to be stored with auxin since their plants had been deprived of leaves or kept in the dark. By the end of the experiment auxin was estimated according to the diffusion method (Table 5).

Table 5

Auxin Production in Apical End of *Vicia faba* Grown on Glucose Solution

Sets No.	Conditions: Illumination / Solution	Duration of experiment				
		13.IV—25.IV	1.VI—5.VI	19.VI—25.VI		1.X—5.X
		Daylight			Darkness	Daylight
1	3% glucose	5±0.89	6±1.03	4±0.96	5±1.12	7±1.30
2	Tap water	0	0	0	0	0

Here too the influence of the leaves was eliminated and we have to conclude that auxin has formed in the growing points out of sugars. This goes to refute the suggestion made by Thimann and Bonner (6) that the rôle of the leaves in synthesizing auxin is to store up its «precursor».

The mechanism of auxin formation in a green plant may be traced as follows: the assimilates stored up in the leaves are through the agency of photosynthesis conveyed to the growing buds, where the synthesis of auxin takes place at the expense of sugars. From the buds as centres of its formation the auxin flows out to the stem portions and leaves located below.

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* The tips shared with the leaves the respective illumination.

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PLANT PHYSIOLOGY

QUALITATIVE VARIATIONS OF RUBBER IN THE ROOTS OF KOK-SAGHYZ AT THE SECOND YEAR OF VEGETATION

By S. M. MASHTAKOV

(Communicated by N. I. Vavilov, Member of the Academy, 4. VI. 1939)

In our preceding paper ([2]) we have shown that rubber in the roots of kok-saghyz at the first year of growth is at the beginning of its formation in the stage of low polymerization. As the plants grow, the percentage of rubber and its molecular weight steadily increase, reaching their maximum value by the beginning of winter period.

The development of kok-saghyz during the second year of vegetation is different from that during the first year in that it is followed by the process of sheath formation previously described by Rudenskaja ([3]). Qualitative and quantitative determinations of rubber in the roots of kok-saghyz were therefore made separately in the new tissue, in the sheath, and in the root as a whole (together with the sheath). Both procedure and conditions of the experiments were the same as in the previous work.

The samples of the roots of two year kok-saghyz were taken for these experiments at following dates: 21 April—time of appearance of leaf rosette (soon after thawing); 31 May—stage of flowering; 14 June—stage of fruiting; 5 July—end of fruiting and single cases of transition to the period of summer dormancy; 27 July—period of full dormancy; 4 October—second period of growth; 27 October—second period of vegetation.

The dry weight of the sheath and of the new root tissue has changed in the course of kok-saghyz development in the following way (Table 1).

Table 1

Change in the Mean Weight of Dry Root in g

	21/IV	31/V	14/VI	5/VII	27/VII	4/X	27/X
Root without sheath (new tissue)	—	0.40	0.84	1.25	1.68	1.45	1.4
Sheath	—	0.87	0.66	0.33	0.27	traces	—
Root together with sheath	1.01	1.27	1.50	1.58	1.95	—	—
Ratio of sheath to new tissue	—	2.18	0.78	0.26	0.16	—	—

The data of Table 1 show that the process of organic matter accumulation in the roots of two-year old kok-saghyz goes along with the loss of sheath mass. The increment of dry matter in the new tissue, however, proceeds so

fast that the total weight of the root (sheath including) increases in the process of growth up to the period of summer dormancy. After this period the root weight lowers owing to the total destruction of the sheath and partial loss of the organic mass of the new tissue. The variation of relative (in %) and absolute rubber content at different dates is shown in Table 2.

Table 2

Per cent and Absolute Content of Rubber in the Roots of Two Year Old Kok-saghyz

	21/V	31/V	14/VI	5/VII	27/VII	4/X	27/X
Rubber. Root without sheath (new tissue) in % .	—	4.60	5.15	6.20	5.40	6.12	7.16
In g for 100 plants	—	1.84	4.33	6.50	9.07	8.87	10.10
Sheath in %	—	17.11	19.18	20.85	33.10	—	—
In g for 100 plants	—	14.83	12.67	6.88	—	—	—
Root together with sheath in %	11.60	11.00	11.07	7.27	7.36	—	—
In g for 100 plants	11.72	13.97	16.69	11.49	14.35	—	—
Resins in %. Root without sheath (new tissue)	—	2.36	1.83	2.14	2.02	2.16	2.42
Sheath	—	3.50	3·27	5.47	5.92	—	—
Root together with sheath . .	3.26	2.89	2.42	2.71	2.33	—	—

These data show that in the new root tissue of kok-saghyz in the course of its vegetation both the absolute and relative rubber content gradually increase.

The rise in the rubber per cent during the period from 27/VII to 4/X was due to the loss of organic mass. Alongside of this, the absolute quantity of rubber remained practically unchanged during that period. The per cent of rubber in the sheath rises, while its absolute content diminishes, its maximum reduction being observed at the period when the greatest part of the sheath mass is already destroyed.

The content of rubber in the root as a whole varies depending on the rubber content in the sheath and the new tissue. In this case the per cent of rubber rises at the beginning (by 14/VI) to drop next, evidently in connexion with the maximum loss of rubber in the sheath which occurs at this period.

The qualitative alterations of rubber were investigated by determining the relative viscosity of benzene solutions and the molecular weight, according to Staudinger. The results of these determinations are given in Tables 3 and 4.

From Tables 3 and 4 it may be clearly seen that the viscosity of benzene solutions of rubber and its molecular weight in the new tissue of the root as well as in the roots of one year old kok-saghyz regularly vary tending to increase. At the end of vegetation, the rubber contained in the new root tissue becomes qualitatively equivalent to that of the autumn samples of one-year old kok-saghyz, and of the early spring samples of the one-year old kok-saghyz.

The qualitative indices of the rubber contained in the sheath are the highest at the first dates. The viscosity of the solutions and the molecular weight of rubber up to the middle of June exceed considerably the respective indices of the new root tissue rubber. Further on in connexion with severe destruction of the sheath, depolymerization takes place and, consequently, a sharp drop of molecular weight of the rubber. The destruction of the sheath seems to be due to the intense activity of soil microorganisms (1). At the beginning takes place the loss of the most mobile elements of the sheath (carbohydrates, proteins, etc.), later on, that of rubber. Therefore, along

with the growth of the roots of two-year old kok-saghyz there is always observed an enrichment of the sheath with rubber which, however, later on is also destroyed and disappears altogether.

Table 3

Relative Viscosity of Benzene Solutions

Date	Concentration of solution in %	0.5	0.25	0.125	0.05	0.025
		above 0.0735	0.0367	0.0127	0.00735	0.00367
21/IV	Root together with sheath .	17.48	5.41	2.60	1.56	1.27
31/V	Root without sheath (new tissue)	9.87	3.68	2.04	1.34	1.16
	Sheath	17.60	5.19	2.44	1.56	1.27
14/VI	Root together with sheath .	17.35	5.21	2.58	1.52	1.26
	Root without sheath (new tissue)	11.91	4.12	2.23	1.40	1.19
	Sheath	18.17	15.39	2.66	1.54	1.27
5/VII	Root together with sheath .	17.02	5.18	2.54	1.51	1.26
	Root without sheath (new tissue)	12.00	4.16	2.24	1.42	1.20
	Sheath	7.00	3.00	1.80	1.30	1.15
27/VII	Root together with sheath .	10.15	3.9	2.13	1.40	1.20
	Root without sheath (new tissue)	14.30	4.36	2.41	1.46	1.22
	Sheath	6.97	3.00	1.82	1.29	1.14
4/X	Root together with sheath .	12.90	4.56	2.34	1.49	1.24
	Root without sheath (new tissue)	17.68	5.12	2.55	1.52	1.25
27/X	Root without sheath	18.71	5.30	2.62	1.56	1.27

Table 4

Molecular Weight and Degree of Rubber Polymerization

	21/IV	31/V	14/VI	5/VII	27/VII	4/X	27/X
Root without sheath (new tissue)							
Mol. weight .	—	149900	176700	181100	209200	231400	249600
Degree of polymerization . .	—	2200	2590	2660	3070	3400	3670
Sheath							
Mol. weight . .	—	251900	245000	136100	129300	—	—
Degree of polymerization . .	—	3700	3600	2000	1900	—	—
Root together with sheath							
Mol. weight . .	249500	238900	238900	181500	220100	—	—
Degree of polymerization . .	3670	3530	3530	2660	3240	—	—

The rubber contained in the whole root (sheath included) of early spring samples is qualitatively not inferior to that of the autumn samples of one year old kok-saghyz.

The run of the curve of rubber viscosity remains almost unchanged up to the end of May or even to the middle of June. At the end of fruiting (prior to the transition to dormancy) the viscosity and polymerism indices of rubber decrease markedly, which is connected with drop in the

qualitative indices of rubber in the sheath and a rather low quality of rubber in the new root tissue.

The data obtained permit of the suggestion that the harvest of kok-saghyz roots may possibly be transferred to the spring period in the cases of industrial requirement, since the relative viscosity of the solutions and the molecular weight of rubber which determine its technical qualities remain unchanged during the winter period and do not decrease during the first six weeks of the second vegetation. The qualitative variation of resins contained in the roots of two-year old kok-saghyz were determined after their acid number and index of refraction (n_D^{20}). The results obtained are summed up in Table 5.

Table 5

Physical-Chemical Constants of Resins

Constants		21/IV	31/V	14/VI	5/VII	27/VII	4/X	27/X
New tissue	Acid number	—	41.01	46.92	73.37	75.53	95.63	—
	Index of refraction . .	—	1.5215	1.5199	1.5180	1.5152	1.6088	1.5070
Sheath	Acid number	—	38.15	35.78	31.43	26.96	—	—
	Index of refraction . .	—	1.5305	1.5320	1.5144	1.5269	—	—
Root together with sheath	Acid number	41.16	39.38	42.47	60.69	66.17	—	—
	Index of refraction. .	1.5197	1.5197	1.5280	1.5180	1.5180	—	—

The data of Table 5 permit to conclude that the qualitative composition of the resins contained in the roots of both one and two-year old kok-saghyz vary in the course of the plant's development.

Acid number of resins in the new root tissue increases, while the index of refraction falls. The variation of these fundamental indices in the new tissue of two-year old kok-saghyz proceeds in the same succession as in the roots of kok-saghyz of the first year of vegetation.

In the root as a whole (including sheath) the acid number proves higher. The acid number of resins in early-spring samples (21/IV) is considerably lower (by 60%) than in late-autumn samples of kok-saghyz of the first year of vegetation. Evidently, the organic acids entering the composition of resins undergo certain changes in the course of metabolism during the winter period of dormancy and particularly by the time of spring-vitality rise.

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AGROPHYSIOLOGY

BIOCHEMICAL FEATURES OF ALPINE FODDER PLANTS

By S. O. GREBINSKY

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Biochemical investigation of alpine plants has in the first place disclosed that they are rather high in sugars (1), alkaloids, essential oils etc. It is also claimed that the quality of the essential oils and the fatty oils in the flax seed(2) and the bark of trees (3) varies with the altitude.

Ivanov and co-workers have reported (2,3) that the cereal seeds grown in mountains decrease in proteins and show enhanced enzymic activity.

According to Baranov (5) the plants cultivated in the Pamirs at an altitude of 4000 m are very high in soluble sugars, vitamin C and oil. The latter is stored here in considerable amounts by the leaves.

In spite of its great economic importance, the question as to the biochemistry of alpine fodder plants has scarcely been discussed in literature. Some few data on the chemical composition of the hay grown in high localities are no sufficient basis for any general conclusion to be drawn from them. If we were to compare, for instance, the data referred to by Zakhariev and co-workers (6) on the chemical composition of the tall-grass hay from the high meadows of Kirghizia with the chemical analysis of a steppe hay containing grasses of varying size and kind, we would be apt to make a conclusion that the alpine hay is higher in nitrogenous substances and ash and lower in cellulose. There is also a tendency to draw this conclusion from some of the data in the tables by Popov and Elkin (7) in which the means of numerous estimations made in different mountain and plain localities of this country are summarized. However, what these authors have analyzed were not individual plants but their miscellany in the form of hay. This is why in the other works, not excepting the other works of Zakhariev (8,9), we can harldy observe any appreciable difference in the composition of hay harvested at different altitudes. Comparative investigation of individual fodder grasses was carried out in Hawaiian Islands (10) at altitudes of 702, 915 and 1311 m and this has shown the content of ash to increase with the height, while the maximum accumulation of nitrogen in the summer months was observed at the height of 915 m. In that work whole plants were analyzed. Concerning the chemical changes taking place in the leaves of alpine plants it is known that they contain no starch in their tissues except in stomatal cells (11). At high altitudes the leaves of *Caltha* become thicker and contain less water and ash but increase in osmotically active substances (12).

The comparative data set forth in the present communication have been obtained by analyzing some fodder plants from Ala-tau, a high locality

in the neihgbourhood of Alma-Ata. The investigation had for object to throw light upon the biochemical relations in certain fodder plants characteristic of the humid mountains of Kazakhstan and to ascertain their nutritional value. The region investigated rises gradually from the foot-hills adjoining the town Alma-Ata, ranging in height from 900 to 1000 m, and reaches the snow-bound zone at an altitude of 3500—3700 m, 20 km south and south-west of the town. Though the range of variation with respect to height is very wide and amounts to 2000 m, it is a simple matter to refer the altitudes investigated to two main zones. The first embraces the localities between 1400 and 2400 m which if compared to the conditions prevailing at Alma-Ata show increased humidity (848 m) and a rather high mean temperature (12°—14°) during the period of grass vegetation. The meadow-grasses are here breast-high. In the second zone the temperature is considerably lower (5.6° C), but the precipitation is no less abundant (800 mm).

It should be noted, however, that the soil above 2400 m is much more sparingly provided with humus; the water supply is likely to suffer from this disadvantage in spite of copious precipitation. Fir-woods are not encountered above 2700 m; herbaceous plants decrease in size and approach to the xeromorphous type as we rise toward the belt of alpine meadows.

In the summer of 1938 some kinds of fodder plants were collected at varying altitudes in this region. These were largely the species of wide distribution range—from foot-hills to alpine meadows—say, *Geranium collinum* Steph. and *Ligularia macrophylla* D. C. The latter have their size, and especially the size of their leaves, decreasing with the altitude considerably. The collection involved also some other species of more narrow elevation range.

The altitudes were taken by means of an altimeter. The plants were gathered at 7 a. m. and killed in the steam. A few more collections were made in the evening between 6 and 7 p. m. The plants were brought to the laboratory where they were shredded (leaves, stems and all) and tested for their chemical composition. The total of water soluble sugars and insoluble (reserve) carbohydrates were estimated in the aliquot subjected to hydrolysis with 2% hydrochloric acid during three hours. Raw cellulose, total nitrogen and ash were determined in the usual way. The sugars were estimated according to Bertrand. The following is an account of the results obtained.

Geranium collinum Steph.—perennial herb, pubescent, with a branchy stem. It is eaten with pleasure by sheep and not so by cow ([13]). When a height of 3000 m is reached by this plant it loses its stem entirely.

Table 1 presents data obtained from analyzing the morning and the evening collections of geranium gathered at varying altitudes. All plants were flowering at that time.

Not only are the enhanced storage of nitrogen containing substances, the increased ratio of soluble sugars in the total of carbohydrates and the decrease in reserve carbohydrates and cellulose characteristic of the plant as a whole, but all these phenomena are also observed when only the leaves are analyzed (Table 2).

In *Ligularia macrophylla* the leaves alone were gathered and tested. This big perennial is scarcely investigated as fodder plant. Its leaves, according to recent observation made in Kirghizia, are enjoyed by animals ([13]). It is known moreover that they decrease in size with increasing elevation.

This analysis differs from that of whole plants in the content of ash decreasing gradually with increasing elevation. This is probably because the leaf becomes thicker. The analytical data on other plants, which have been derived however from less abundant material, show a similar trend of biochemical changes, yet it is not so pronounced for these plants their stem and leaves being not so strongly reduced in response to increasing

Table 1

Chemical Composition of *Geranium collinum* Steph. with Reference to Elevation. (Whole plants analyzed at the stage of flowering. The percentage of respective substances is reported on a dry mattter basis*)

Elevation in m	N × 6.25	Soluble sugars	Reserve carbohydrates (hydrolyzed with 2% HCl for 3 hours)	Total of carbohydrates	Raw cellulose	Ash	% of soluble in total carbohydrates	Date of collection
			Morning Collections					
1450	8.72	2.86	12.55	15.41	22.42	6.34	18.50	13 VII
2700	17.57	4.38	8.11	12.49	18.67	8.63	35.07	17 VII
3150	17.64	4.36	6.00	10.36	14.14	9.00	42.49	16 VII
			Evening Collections					
1450	8.11	2.83	12.16	14.99	—	6.04	23.27	18 VII
1900	11.04	2.84	11.16	14.00	—	7.40	20.80	16 VII**
2550	15.74	3.27	7.02	10.29	—	9.50	31.77	17 VII
2800	15.80	4.38	9.90	14.28	—	9.45	30.67	16 VII
3000	18.11	4.08	6.02	10.10	—	12.02	40.38	19 VII**
3150	17.03	4.03	4.17	8.17	—	10.50	49.32	19 VII

* The substances determined by direct methods take up 51—59% of the total dry weight. The rest is made up by resins, fat-like substances, partly by pectins, also by organic acids etc. which were not estimated. Direct estimation of various substances is rarely known to discover more than 80% in dry matter, because the coefficients used in recalculation, say after hydrolysis with strong acids, are inexact.

** Plants were dried in the sun.

Table 2

Chemical Composition of Leaves of *Ligularia macrophylla* D. C. from Varying Altitudes (in % on dry weight basis)

Elevation in m	N × 6.25	Soluble sugars	Reserve carbohydrates (hydrolyzed with 2% HCl for 3 hrs)	Total of carbohydrates	Raw cellulose	Ash	% of soluble in total carbohydrates	Date of collection
			Morning Collections					
1900	12.69	5.55	12.28	17.83	—	16.52	31.13	10 VII
2625	—	4.38	4.10	8.48	—	15.65	51.76	10 VII
3150	19.69	5.60	4.00	9.60	—	14.93	58.33	15 VII
			Evening Collections					
1900	13.08	3.27	10.24	13.51	16.47	16.11	24.20	10 VII
2750	14.98	4.03	7.66	11.69	12.52	14.91	34.47	10 VII
3100	24.12	4.37	4.59	8.96	12.16	14.00	48.54	15 VII

altitude. Thus, the vetch increases in nitrogen containig substances from 17.73 to 21.3% as it rises from a 1800 to a 2625 m altitude respectively. Accordingly these data for *Poa* are 9.35% at 1000 and 12.33% at 2625 m.

Considering the results obtained in the light of the fodder problem it is well to note that the increased storage of protein and ash at the expense of the cellulose by the alpine grasses is a factor of high nutritional importance. This increase is more intensive in those plants which respond to increasing altitude by decreasing their frond area considerably. Accordingly, an increase in frond area will increase the nutritional value of alpine meadows by enriching the plants with protein and ash.

Another interesting point to note here is the abundant storage of nitrogen containing substances by *Ligularia macrophylla* at high altitudes. This is evidence of it being possible to grow plants high in protein in alpine meadows on soils low in nitrogen.

It is worth while to point out in conclusion that the leading factors in the metabolism of alpine plants is the reduced temperature and the limited water supply both being characteristic of high localities.

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CYTOLOGY

A HAPLOID PLANT OF *SOLANUM TUBEROSUM* L.

By E. V. IVANOVSKAJA

(Communicated by N. I. Vavilov, Member of the Academy, 2. VI. 1939)

V. I. Sadovnikova (Leningrad Potato Station) has obtained from a seed, produced by crossing late maturing variety *Aurora* (*Solanum tuberosum* L., $2n=48$) ♀ with *Solanum Rybinii* Juz. et Buk. ($2n=24$) ♂, a plant whose chromosome number ($2n$) was determined by us to be equal to 24. This plant had no characters of *S. Rybinii* but differed from *Aurora* in a number of characters.

The peduncle of this plant, the calyx, the corolla and its reddish-violet colour, ruffledness, the shape of acumens (Fig. 1, *A*), of arms, bent anthers, did not differ from the corresponding characters of the maternal form, *Aurora*; the same was true of the tubers which were pink with darker eyes. On the other hand, it had 6—7 paired leaves which were considerably less pubescent, and differently dissected (Fig. 1, *B*); they differed in the shape of segments, possessed thinner blades and showed marked tapering. The plant was not as tall, had somewhat different branching habit, its tubers were smaller and differed in shape, etc. Petals were thinner than in *Aurora* and could be easily torn. The whole flower was somewhat smaller and possessed an agreeable fragrance (those of *Aurora* have none). The plant formed a great number (50—100) of small tubers of slightly elongated shape compactly stored in a small hole. Tubers of *Aurora* are large and rounded. The proportion of starch in tubers (10.7 per cent) was somewhat lower than in *Aurora*. At the beginning of the summer the plant was behind in development and greatly suffered of cabbage-aphid.

The plant was characterized by a mass development of axilliary shoots at the base of the main stems which had there very short internodes. It flowered abundantly during the second half of the summer.

Three ways of origin of the plant in question could be suggested: 1) the plant with 24 chromosomes might have plasm of *S. tuberosum* and the chromosomes of *S. Rybinii*, i. e. it could owe its origin to androgenesis; in this case the male generative nucleus which had entered the egg-cell should have had somatic chromosome number and the nucleus of the egg should have had degenerated; 2) it could be a hybrid which had arisen from the union of a «semi-haploid» 12-chromosome gamete of *Aurora* with a haploid 12-chromosome gamete of *S. Rybinii*; 3) it could arise as a result of generative parthenogenetic development of the egg-cell or of generative apogamy.

In all known cases of androgenesis the plant repeated the paternal type; however, morphological analysis failed to detect in this plant any character

of *S. Rybinii*. It could evidently be no hybrid either, since meiosis is relatively regular in the 48 chromosome *Aurora*, so that the production of a 12-chromosome gamete is of very low probability. *Aurora* is self-fertile; in 1938 it produced 3 berries on 10 plants which were naturally self-pollinated. The plant in question should be thus with most probability considered as arisen from parthenogenetic development of the egg-cell or from generative apogamy; in both cases it should be regarded as a haploid of *Aurora*.

Haploids are known to occur in a great number of different genera: in *Crepis*, *Datura*, *Nicotiana*, *Oenothera*, *Triticum* etc. ([1,2]). They have

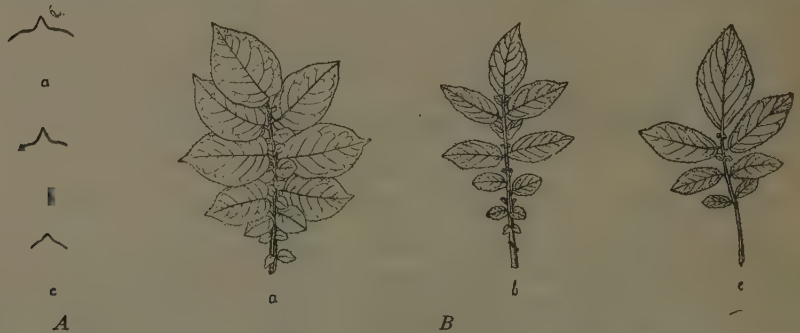


Fig. 1. Acumens (*A*) and leaves (*B*) in: *Aurora* (*a*), haploid plant of *Aurora* (*b*) and *S. Rybinii* (*c*).

been obtained in interspecific crosses, by treatment with high and low temperatures, by pollination with X-rayed pollen, as well as found to occur spontaneously and among twin-seedlings.

In the genus *Solanum* haploids belonging to two species are known: the haploid of *S. nigrum* L., $2n=36$ obtained from pollination of *S. nigrum* with pollen of *S. lutenum* and from self-pollination of a periclinal chimera of *S. nigrum* ([3]); the other is the haploid twin $2n=24$ found among the progeny of a tetraploid F_1 *S. chaucha* × *S. tuberosum* ([4]).

Bivalents in varying numbers from 3 to 12 were found to be formed in the former whereas in the latter 12 bivalents occur in the PMC.

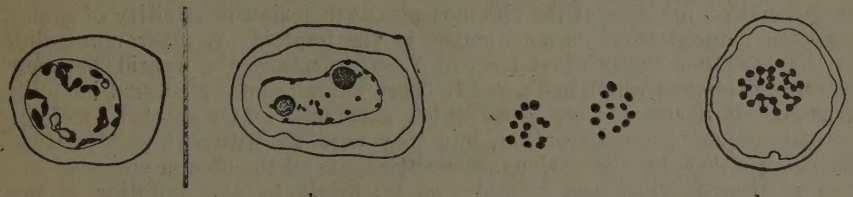
In the haploid of *Aurora* 12—11 bivalents are formed at meiosis (some show two chiasmata); 1—2 elements are often outside the plate; sometimes two chromosomes are found to be connected with the nucleolus (Fig. 2, *a*). At the anaphase of the I division chromatin bridges are found (about 7 per cent of cases). The plates of the metaphase of the II division are regular, 11—12—13 elements are found (Fig. 2, *b*) one of which often lying in the plasm.

In a corner of one of the anthers the following subsequent stages were found: monocentric (Fig. 2, *c*) and dicentric interkinesis, both presenting grotesque aspects as a result of the I division taking place in some special irregular manner. Then followed meta-anaphases with a single spindle or rather early metaphases of the II division formed of cells with suspended I division. Further were located II metaphases of two types which showed somatic chromosome numbers: with a rounded regular plate formed of cells with suspended I division (Fig. 2, *d*) and those with plates formed of two fused plates of the II metaphase which had formed of dicentric abnormal interkinesis. Then followed anaphases and telophases of the II division of the cells with somatic chromosome numbers; both had only two centres. The remaining huge area of the locule was filled with normal telophases of the

II division with 4 centres; among them were scattered very rare telophases of the II division with 2 centres.

Along with entirely normal divisions resulting in gametes with 12 chromosomes, in certain isolated portions of the anthers of the haploid a division was observed which resulted in 24 chromosome gametes. It is difficult to say what are the specific conditions of such a portion compared with the main part of the anthers. No visible injury could be detected in anthers at these particular places. All the material was fixed at the same time in August 1937.

Normal division produced 4-centre telophases and then regular tetrads (very rarely—pentads). On slides containing telophases and tetrads one could also observe two different divisions: among a great many locules filled with



a *b* *c* *d*

Fig. 2. Meiosis in the haploid plant of *Aurora*: diakinesis showing 12 bivalents (*a*), metaphase of the II division with plates containing 12 chromosome each (*b*), interkinesis with somatic chromosome number (*c*), metaphase of the II division with somatic chromosome number (*d*). × 3200.

tetrads suddenly a corner or a little portion was found which was filled with regularly shaped dyads. In other cases isolated dyads were found but occasionally.

In one anther containing pollen (a group of ovules at the prophase stage was found on it), a very small adventive locule was found which showed all the meiotic stages at once. The division proceeded irregularly, in some of the cells at the diakinesis one could count 24 elements. The cells of this locule formed a dense tissue and possessed a very elongated shape.

Fig. 3. Two embryosacs of *Aurora* formed from two tetrads. × 1600.

A characteristic feature of the macrosporogenesis of both the haploid and *Aurora* proved to be the differentiation of two embryosac mother cells (Fig. 3). Macrosporogenesis took place not synchronously with microsporogenesis. Thus, in *Aurora* the first division in the ovule begins at the moment when pollen is already formed in the anthers. A very small proportion of embryosacs (which varies with the pistil and even locules) degenerate.

At the macrosporogenesis of *Aurora* as well as at microsporogenesis, 24 elements were observed at the metaphase of the I division while 1—3 were observed out of the plate. Isolated trivalents and quadrivalents were met with. At diakinesis two pairs of chromosomes connected with the nucleolus were once observed. At the metaphase of the II division regular plates are formed, 1—2 elements being in the plasm. In one slide meta-anaphases of the II division were met with which had chromosome chains difficult to analyze.

What was the most probable mode of origin of this haploid? The cultivated Columbian *S. Rybinii* crosses with a difficulty with varieties of *S. tuberosum*; however, incompatibility of gametes could hardly play any rôle in the origin of the haploid. Taking into consideration the high proportion of ovules with two twin embryosac mother cells, the parthenogenetic development

of such a normal embryosac is very probable; it could be stimulated by it twin which possibly was fertilized. Stimulation could be also brought about by pollen tubes or by pollen of *S. Rybinii*.

Conjugation of the 24 chromosomes taking as a rule place in the haploid proves the possibility of autosyndesis of the two genomes of *S. tuberosum* and indicates that the «haploid» is as a matter of fact polyploid.

In meiosis of *Aurora* in the great majority of cases bivalents were observed; probably this is a manifestation of greater affinity of genomes.

V. I. Sadovnikova has obtained hybrids of the haploid with several varieties of *S. tuberosum* and the F_2 from natural self-pollination (12 berries, 3 seeds); in the two cases only 23-chromosome gametes were viable (chromosome count of these plants was made by V. I. Ivanov).

Normal conjugation of the chromosomes at meiosis and sterility of gametes with reduced chromosome number in the haploid *S. tuberosum* point to the fact that the original form of *S. tuberosum* was a hybrid between two species each of which had $n = 12$. These chromosomes possessed homologous and similarly arranged genes which were sufficiently related to effect normal conjugational attraction, but they were too different to substitute for one another in the various rearrangements of the chromosomes of the two species. *S. tuberosum* should owe its origin to the doubling of the chromosome-set of such a hybrid, it is thus not a autotetraploid, in which case it would have been normally fertile at the expense of reduced gametes in his haploid, but it should be considered to be an amphidiploid of the type described above.

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